AUTOMOTIVE PRODUCT DESIGN & DEVELOPMENT DELPHI

by

MANUFACTURING, ENGINEERING, AND TECHNOLOGY GROUP

CENTER FOR AUTOMOTIVE RESEARCH

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The statements, findings, and conclusions herein are those of the authors and do not necessarily reflect the views of the project sponsor.

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GLOSSARY

N.A.	North American (United States, Canada, Mexico).
Off-Shore	All other countries not in N.A.
PD&D	Produce Design and Development.
Product Specific Characteristics	Main or major characteristics that define the product. For example, the major characteristics for car bodies are the surface finish, gaps, flush, and crash performance. Some major characteristics for engines are horsepower, torque, and fuel efficiency.

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I. Executive Summary

The automotive industry is currently under enormous economic and political pressures, and companies are responding in radically different ways. This combination of pressures and responses is transforming the industry .From economic pressures such as high raw materials prices (e.g., steel and petroleum) and countries offering low-cost labor to responses such as outsourcing, industry consolidation, and assembly flexibility, no organization can afford to remain static in any of its operations. While manufacturing played a dominant role in the 1990s and still is important today, product development is seeing a resurgence in terms of its importance within the organization. Yet product development is under the same pressures as manufacturing to produce exciting, innovative, cost-effective designs in a short period of time.

This Delphi report describes the North American auto industry's perspective on the current and future state of various issues surrounding the product design process and their impact on product design success. It provides a snap-shot of the current state and 5 year forecast in such areas as business philosophy, product design tools, communication methods and engineering efficiency. The questions were selected based on what are believed to be the major topics affecting product development today and tomorrow.

The Delphi forecast offers the ability to investigate industry trends using a relatively small expert panel. Work done by the Rand Corporation for the U .S. Air Force in the late 1960s indicates that a small panel with an interactive review of results can be a highly effective method of forecasting. The Delphi study utilizes a systematic forecasting process where a panel of knowledgeable experts is asked to respond to a set of survey questions. The panelists were carefully selected based on their positions as well as their companies. They were all middle level to high level managers with titles ranging from director to vice chairman; all are deeply knowledgeable in the subject matter. They were selected from 11 companies: 2 OEMs, 6 Tier 1 suppliers, 2 Tier 2 or higher suppliers, and 1 contract engineering company.

To put the study in perspective, it is important to recognize that the automobile is becoming more complex. Market and social forces are driving the industry to create vehicles with higher levels of performance. This applies not only to their traditional purpose of safely transporting drivers and passengers, but also to the driving experience itself. Technology changes are occurring in every aspect of the vehicle. Innovation in powertrains is occurring everywhere ─from fuel efficient internal combustion engines, clean diesels, and hybrid engines to alternative fuel engines and fuel cells. The number of computer chips and software-controlled systems is increasing at an ever increasing rate. Telematics and communications─both within and outside the vehicle─are increasing, from recording vehicle data to navigation and entertainment systems to continuous electronic communication on demand (e.g., OnStar and web-enabled vehicle communication). This situation creates complexity─not only because the systems themselves are complicated, but also because the interaction between the systems is often difficult to understand and predict. Further, while the market forces demand these systems in the product, they must be designed and produced at lower cost.

Besides the market forces mentioned above, additional factors are driving the industry to structural changes. The industry is getting more efficient, and market share is shifting between companies. This factor has led to overcapacity in the industry, which in turn leads to consolidation. Further, in an effort to lower cost, companies are outsourcing the manufacture (and to some degree the design of subsystems) to suppliers. These suppliers are generally overseas, they are quite competent and have a lower cost structure. This trend is expected to continue (see Section VII.3. Allocation of Developmental Resources). There is also a movement to create new jobs overseas to capitalize on growing market opportunities. And, cost pressures are not expected to abate. Of the 78 different factors studied, final product cost consistently ranked in the top 7─both now and in the future─across all vehicle systems (see Section 1II.3. Overall Weighted Factor Comparison).

It is clear that in addition to the issues discussed above, there will be a significant change in the workforce. A large portion of the baby boomers are expected to retire within 5 to 15 years, leading to a variety of problems. First, as they leave a company, they take their experience and the relationships they have established within and between organizations. Second, the company's health care costs and pension liabilities will increase dramatically.

Lastly, what many feel, but perhaps do not appreciate, is that all the various forces and factors are changing at an ever-increasing rate. This speed of change with the increase in structural complexity brought about through the global economies creates a challenge for organizations to overcome their inherent inertia and respond. While becoming lean was the necessity of the past decade and still is today, it is not sufficient. Agility and the strategies that enable agility is the new paradigm─at all levels of the enterprise and the value chain. Lean is simply one enabler to agility; a lean organization is able to respond more quickly to change. Manufacturing has shown how adding flexibility to a lean manufacturing process can reduce capital investment costs and enable a company to be more responsive to the rapidly changing market demands.

Increased speed is apparent in the ever shorter product development times (see Section VII.5. Development Time). The current development time for a new platform cycle is estimated to be between 29 to 34 months, depending on the OEM. This time is expected to get shorter, approaching 23 to 26 months for a new platform and 17 to 21 months for a carryover platform by 2014. North American and European manufacturers are expected to continue to lag behind the Japanese, but, the gap between competitors is expected to continue to narrow─providing further evidence of the extreme competition in the industry.

Thus, as the industry and individual organizations are experiencing and managing these tremendous changes, product development, too, is changing. Organizations are adopting a number of different strategies to become more lean and agile in product development (see Section IV .1. Business Philosophy Focus). They are: increasing the number of carry-over parts and subsystems, increasing the use of modular designs, increasing the use of CAE and simulation, and increasingly designing globally for global manufacturing. There is no strategy that is viewed to be superior to others; different organizations are focusing on different aspects of all of these strategies. However, these strategies are not deemed as important as some of the more fundamental ways in which product development is changing.

The Delphi panelists believe that the major changes and trends in product development are:

a. Using a more disciplined process (see Section IV.1. Business Philosophy Focus);
b. Transitioning to a greater use of virtual tools (see Section V.2. Impact of Design Tools);
c. Outsourcing more to global suppliers (see Section VII.3. Allocation of Developmental Resources); and
d. Focusing on Design for Manufacturability and Design for Reliability and Durability (see Section V.1. Impact of Design Methods).

The result of these changes in product development is the need for close collaboration and improved communication both within and between organizations. This is the strongest theme that appears to run throughout the study. Approximately half of the top 10 percent of the factors that affect product design are related to communication and collaboration.

However, collaboration is not a natural act, and it requires tools (see Section VI.1. Communication Methods), processes and interpersonal relationships. When asked which functions needed to interact and collaborate more, the panel responded that interaction between engineering design and manufacturing, purchasing, and engineering design and suppliers must be improved (see Section VII.2.a. Interactions between functions). When asked how these functions could improve their collaboration, 49 percent of the panel suggested process changes and 18 percent said organizational changes (see Section VII.2.b. Enablers for increased interactions). Clearly, there are improvements that can be introduced to enhance communication and collaboration between these groups.

Collaboration is also occurring between competitors. As the cost of powertrain development becomes more prohibitive, many OEMs (e.g., Ford and GM, DCX and Mitsubishi, and Toyota and Peugeot) are collaborating through various types of partnerships to develop powertrains and transmissions that can be used globally on a variety of vehicle platforms. This trend is not only expected to continue with the OEMs, but may also trickle down to the Tier 1 and 2 suppliers─for example, suppliers may begin collaboration in the powertrain area. This is possible from two trends: (1) powertrains are less of a product differentiator for the consumer, and (2) technology has developed to enable more variants of a basic powertrain to be developed.

The greatest enabler of collaboration is the creation of new internet-based electronic communication tools. Electronic communication is the biggest factor contributing to product development success. The technology has changed the way people communicate; the panel expects this trend to continue in the future, especially as web-based collaboration tools increase and gain acceptance in the industry (see Section VI.1. Communication Methods). These communication tools speed the transfer of the objective information required for coordinated decision making on a variety of issues. However, they cannot completely replace face-to-face meetings. Physical meetings are superior when one must exchange a large amount of complex and subjective information. Team building, strategic planning, negotiations and conflict resolution are some of the typical situations requiring such information exchange. In these and similar situations, it is necessary to build a sense of trust and understanding─most effectively achieved face-to-face.

Processes are also being implemented to help deal with the changing demographics of the workforce. Adhering to an effective disciplined product design process can compensate to some degree for a mobile and changing workforce. As processes are implemented to maintain core competencies, (presumably) the organization can focus on other issues─trusting their process will achieve its goal.

The future challenge for the organization will be how to utilize the intellectual power of the workforce within the organization to innovate faster than the competition. How does one create an environment where ideas flourish and are distributed within the organization? The panel believes that having a more educated workforce, a management that is open to new ideas, ideas shared between product teams, and the distribution of best practices are the most important organizational and human resource management factors (see Section IV .2. Impact of Organizational Factors).

However, the general impact of these human resource issues does not rise above the importance of math based engineering, increased process discipline, and collaboration and communication. These are the most important factors to increasing engineering efficiency (see Section VII.1. Engineering Efficiency). Thus, human resource issues are not as important as increasing engineering efficiency. This is probably because increasing engineering efficiency has a more direct impact on cost than creating an innovative environment. With increased engineering efficiency, fewer engineers are needed to design successful products, thereby reducing overall product development cost.

It is interesting to note that issues typically associated with product design─namely design methods and tools and suppliers─are the issues that have the least impact on product development success. Conversely, communication, design criteria, business philosophy, and HR management are viewed as the most important factors─both now and in the future. We believe this reflects the nature of modern product development. Computer-aided design tools have enabled broad systemization of rudimentary product design tasks. They have raised the importance of proper decision making to meet design criteria through good communication methods between organizationally and geographically dispersed stakeholders, a proper business philosophy regarding the product being designed, and technically competent designers.

However, organizations generally lack the processes that foster collaboration and the communication tools and relationships that permit collaboration to occur, especially at the higher levels of the business. At the detailed engineering and operational levels, these processes can and have been established for many global companies. Some have successfully accomplished 24-hour engineering projects: projects where the engineering work was dispersed to engineering centers globally, such that the project was being worked upon by someone somewhere every hour of the day.

Yet, at the higher levels of management where decisions are more difficult to justify, collaboration is based upon relationships between people. As people retire, the relationships they have established are also lost. Reestablishing the relationships using current processes and communication channels takes time and bears significant risk as it may not result in the desired collaboration. Indeed, most communication is not designed to establish collaborative relationships between disparate functions and organizations. Further, most processes are not designed to facilitate communication to establish collaborative relationships. Collaboration is not a natural act; collaborative relationships are based on trust.

Some panelists commented on the customer-supplier relationship which has come under increasing industry attention in recent years. It has been reported in the media that, as the domestic OEMs have come under increasing competitive pressures, they have in turn pressured their supply chain, and in some cases, implemented practices that created an antagonistic rather than collaborative relationship. These practices appear to be directed to move the risk from the OEMs to the supply chain. The impression (echoed by some of the panelists) is that the transplants have a better relationship with their supply chain.

Several factors have contributed to the situation. First, the domestic OEMs are fighting for survival and the cost pressures they experience are being passed on to the supply chain. This was echoed by the panel by stating product cost as the most important supplier attribute (see IV.3. Impact of Supplier Capabilities). This factor is not expected to change in the future. Second, the OEMs are becoming more efficient in all areas of their operations, evidenced by the narrowing gap in lead time reduction (see VII.5. Development Time). Further, with greater efficiency, they can do more with less. Thus, OEMs may outsource less in certain areas, such as bodies, running counter to the supply chain expectation (see VII.3.b. Body and Chassis / Suspension).

We believe the industry will undergo a structural change. As more companies become more efficient, and without a significant increase in market demand in the local geographic markets, the current capacity in the supply base will necessarily shrink.

The whole topic of the customer-supplier relationship and supply chain management is of critical importance. Collaboration and communication, both in terms of the technology as well as in terms of increasing understanding between disparate groups, has been a major theme that has been touched upon by the panel repeatedly throughout the study. While more and more of the vehicle is being outsourced to the supply base, media reports of collaboration tend to be between competitors. This collaboration is particularly true in the powertrain area─exemplified by GM and Ford collaborating on transmissions, GM and DCX on hybrid technology, or Toyota and PSA on a joint engine. Fewer, if any, reports exist on vertical collaboration with the supply chain.

Yet, the panel recognizes the need for better communication and earlier involvement (i.e., collaboration) of the supply chain, particularly in the area of product design and manufacturing, if the whole system is to reap further gains in efficiency and shorter product lead times. And in Section VII.2.b. Enablers for increased interactions, panelists mention some suggestions as to how communication could be improved. But these types of changes, while a start, are clearly insufficient to address the broader customer-supplier relationship issue. And while supplier relationships and supplier management have a profound effect on product design by the mere fact that more and more of the vehicle is being outsourced, it is beyond the scope of this study to investigate and address these issues in detail.

We encourage the industry to open a dialogue to address this important issue.

II. Introduction

Background
This Delphi report describes the North American auto industry's perspective on the current and future state of various issues surrounding the product design process and its impact on product design success. The Delphi forecast affords the ability to investigate industry trends using a relatively small expert panel. While the Delphi panel is small when compared to a traditional survey, work done by the Rand Corporation for the U.S. Air Force in the late 1960s indicates that a small panel of experts with an interactive review of results can be a highly effective method of forecasting. The Delphi forecasting process is a systematic forecasting process where a select panel of knowledgeable experts is asked to respond to a set of survey questions. The responses are statistically analyzed, and shown to the panel. Depending on the resulting level of consensus, the individual panelists are invited to revise their original responses. This process helps develop a consensus in opinion-based surveys.

The automotive industry is currently under enormous economic and political pressures, and different companies are responding in radically different ways. The combination of these pressures and responses is transforming the industry. From economic pressures such as low-cost labor countries and high raw material prices (e.g., steel and petroleum), to responses such as outsourcing, industry consolidation, and assembly flexibility, no organization can afford to remain static in any of its operations. While manufacturing played a dominant role in the 1990s and still is important today, product development is seeing a resurgence in terms of its importance within the organization. Yet product development is also under the same pressures as manufacturing to produce exciting, innovative, cost-effective designs in a short period of time.

This survey provides a snap-shot of the current state and 5-year forecast in such varied areas as business philosophy, product design tools, communication methods and engineering efficiency. The topics were selected based on what are believed to be the major topics affecting product development today and tomorrow.

Structure of study
The study was divided into four major categories:

I. Business philosophy, organizational factors, and supplier capabilities
II. Design methods tools and criteria
III. Interactions and collaboration
IV. General/Other topics

The study consisted of two basic types of questions. The first type was a traditional question where the panelist was asked to provide an estimate or an open response. In the second type of question the panelist was asked to rank a variety of factors by distributing 100 points between the various choices. Then by asking the panelists to rank the various questions against each other, it was possible to determine the relative weights of all factors in the survey. These types of questions are called weighted questions.

Panel Characteristics and Composition

CAR's long standing relationship with the industry permitted a good selection of panelists based on their company and their position within the company. The completed panel consisted of 21 individuals from 11 companies: two OEMs, six Tier-1 suppliers, two Tier-2 or higher suppliers, and one contract engineering company. Each company responded with only 1 voice. The panelists are all middle-to-high level managers with titles ranging from director to vice chairman; all are deeply knowledgeable in the subject matter.

The names and identities of the panelists and companies are known only to CAR and are maintained in the strictest confidence. The responses are coded, and do not reveal the identity of the panelists.

Presentation of Forecasts and Analyses

The study is separated into five sections. The first four sections involve the weighted questions. Weighted questions were presented to the panel in three levels: a lower level individual question, and two higher level questions that asked to rank questions against each other within a category and then to rank the categories against each other. The first section will present the results of these higher level rankings. The second through fourth sections will present the weighted results of the individual questions by category. The fifth section presents the results of the unweighted and open-ended questions.

For questions requiring a numerical response (such as the weighted questions), the analysis will present the verbatim question posed to the panel, a table of the median and the 25th and 75th quartile of their responses, and a graph of their median scores. Note that the median score is simply the middle value. It is a measure of central tendency and is preferable to the mean score for relatively small samples as it is less sensitive to extreme values. It should also be noted that, since we are using the median instead of the average, the responses for the weighted questions typically will not sum to 100 percent. The difference in the quartiles is called the inter-quartile range (IQR). It is a measure of dispersion and is preferable to using standard deviation for small samples. It is a measure of the degree to which panelists achieved consensus on an issue.

Stating the individual quartiles instead of simply the IQR also provides a measure of how centered the median is with respect to the quartiles. For example, in a question asking for a relative ranking based on 100 points, a median response might be 25 percent with an IQR ranging from 15 to 35 percent—meaning that 50 percent of the responses varied from 15 to 35 percent, with the middle responses being 25 percent. The narrow IQR would indicate that the panelists generally agreed on this issue. Conversely, if the IQR ranged from 15 percent to 65 percent, it would indicate considerable disagreement and uncertainty among the panelists.

No statistical tests have been conducted. Also, for the questions relating to specific subsystems, only the subsystems that had 5 or more responses were analyzed. Some systems were analyzed together based on their similarity and are so noted in the analysis.

Selected edited comments of the panelists are also presented. These comments are edited only to provide anonymity to the panelist. They are presented to provide insight into the panelists' thinking. Sometimes, they indicate alternative factors that were not presented in the study.

(These factors are not included in the weightings, as they seldom occurred. They should induce the reader to think more deeply about the question and its implications.)

Following the tables and graphs, there is a discussion of the major conclusions that can be drawn from them. This discussion will be combined with CAR's knowledge of the industry and current events to provide some perspective to the numerical results. Also, where appropriate and possible, the results from this Delphi will be compared to a similar Delphi study conducted by the Office for the Study of Automotive Transportation (OSAT) at the University of Michigan in 1998. CAR's chairman (Dr. David Cole), its president (Dr. Jay Baron) and many staff members were part of the OSAT staff when this study was conducted. This study is still available for purchase from OSAT.

While the current study may seem similar to a standard survey, there are distinct differences. First, it is not based on a random sample of respondents, but is based on the opinions of selected individuals considered experts in their fields. Second, it is not designed to capture the opinion of the industry in the sense of surveying the majority of the industry participants. The purpose of the study is to raise the reader's awareness of the issues, and to present the opinions of a select group of experts in the field. We hope this document will provide a starting point for discussion on the many important issues addressed here.

III. Weighted Analysis

The weighted questions were divided into 3 major categories, each consisting of several questions. The panelists were asked to rate various factors within each question. The major categories were:

1. Business Philosophy, Organizational Factors and Supplier Capabilities
2. Design Methods, Tools, and Criteria
3. Interactions and Collaboration

In the highest level question, the panelists were asked to score the importance of the three categories relative to each other. The next level questions asked the panelists to score the importance of the questions within each category relative to each other. Finally, the questions asked the panelists to score various factors relative to each other. By computing the product of these various scores, it is possible to determine the relative importance of all of the study's weighted factors.

While the complex structure of the questions allows one to compare the relative importance of all 78 factors studied, it makes reading and interpreting the report somewhat difficult. The weighted questions ask the panel to distribute 100 points across the various factors. In the analysis, the factor weights are multiplied by the question weights and the category weights resulting in a weighted or relative factor score. Therefore, within the original question category, the relative factor scores no longer sum to 100. For example, the first question on business philosophy asks the panelists to prioritize their companies' business philosophies by distributing 100 points within each factor column (see Section IV.1. Business Philosophy Focus). One panelist's response for the factor "increasing carryover designs" in 2004 was 25%. His overall weight for that question was 40%, and his weight for that category (Business Philosophy, Organizational Factors and Supplier Capabilities) was also 40%. Thus, this panelist's relative factor score for increasing carryover designs was 4% = 0.25*0.40*0.40*100. Since this is done for all panelists across all factors in all questions, the relative scores will no longer sum to 100 within the question.

If one were to sum the relative factor scores across all 78 factors in the study, one would only approach 100 percent, because the median and not the average scores are reported. If average scores were used, then one would reach 100%. However, average scores are not recommended in studies involving a small number of responses.

Due to the structure of the study, it is difficult to integrate and interpret all the information. One way is to compare the relative score to the average score. As there are 78 factors, the average score is 1/78, or 1.3%. Hence, relative factor scores greater than 1.3 indicate that the factor scored above average, and relative scores below 1.3 indicate the factor scored below average.

The results are presented as follows. This section presents the responses to the category and question weightings. It also includes an analysis of all factors queried in the study. The sections following present a detailed analysis of the weighted responses for the various factors by question and category. Further, to the extent possible, each section has been written so that it can be read independently of any other section. Hence, certain sections may repeat material for ease in understanding that particular section.

III.1. Category Weightings

Of the three categories in this survey I, II, and III, please prioritize the current and future influence each has on your company's product design and development success by distributing 100 points in each column.

Table 1. Median and Quartile Scores for Weights of the 3 Study Categories.

Category	Median		Quartile (25/75)	
	2004	2009	2004	2009
I. Business Philosophy, Organizational Factors and Supplier	30	30	28/45	30/38
II. Design Methods, Tools, and Design Criteria	30	30	30/45	30/45
III. Interaction and Collaboration	25	30	20/38	24/40

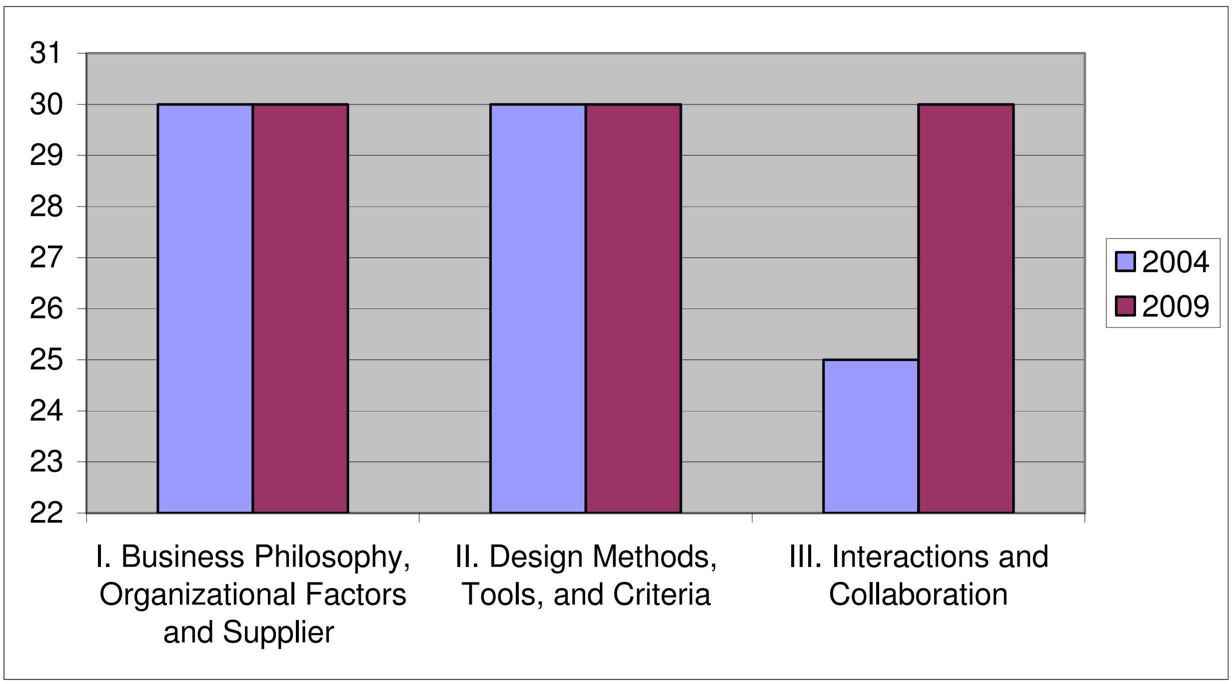


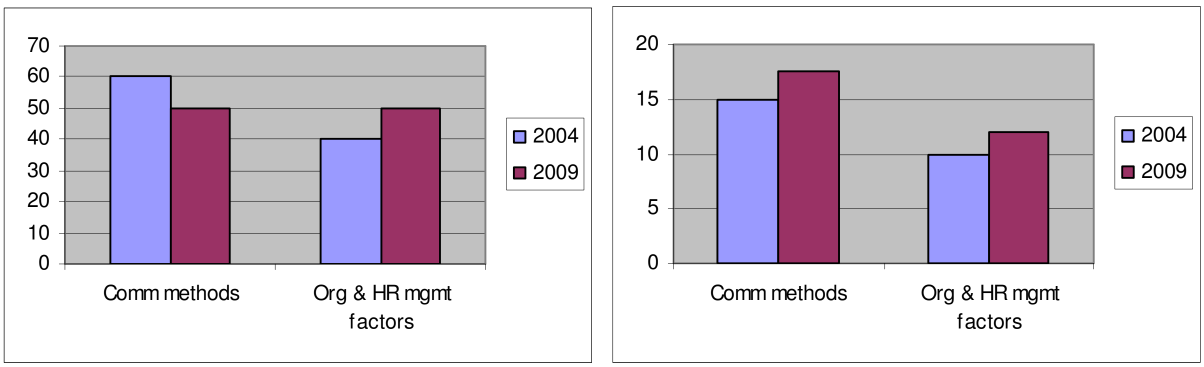
Figure 1. Median Trend of Category Weights.

Discussion and Strategic Considerations:
The panelists clearly believe that design methods, tools and criteria─along with business philosophy, organizational factors, and suppliers─are the most important categories on product development success, followed by interaction and collaboration. In the future, these three categories will be equally weighted as collaboration between groups becomes more important.

It is interesting to note the asymmetry of the responses. For example, the category design methods currently has a median score of 30 (50th percentile), with a 25th percentile response of 30 and a 75th percentile response of 48. This means that the majority of respondents weighted the importance of this category at about 30%, whereas a few individual panelists rated it around 50%. This asymmetry is evident for all categories both now and in the future, with the exception of the future of collaboration, which is much more symmetric. Note that the individual quartiles also increase in the future meaning the panel agrees that collaboration will be the next major area to grow.

III.2. Question Weightings

The question weightings are presented here as a single table, even though the question was stated in three separate sections for ease of response. This analysis also includes the weightings from the category analysis: the individual responses were multiplied by the relative weights from the category analysis. This procedure can have a profound impact on the results. For example, in the analysis of the individual unweighted responses for communication methods and human resource management, the individual responses showed a convergence of opinions (for 2009) to 50%. However, when weighted by the importance of that category for each individual panelist, we find a parallel increase in importance.



(a) Individual Unweighted Response (b) Weighted Response

Figure 2. Comparison of Unweighted versus Weighted Responses for the Example of Communication Methods and Human Resource Management.

The apparent paradoxical outcome occurs because the weights are applied to the individual panelist's response, not to an aggregate score. Thus, the aggregate effect cannot be predicted from simply reviewing the raw scores from the answers. The correct analysis must include the category weightings.

For each of the categories the following question was asked:

Of the questions in this category, please prioritize the current and future influence each has on your company's product design and development success by distributing 100 points in each column.

Table 2. Median and Quartile Scores for Weighted Questions.

Question	Median		Quartile (25/75)	
	2004	2009	2004	2009
I.1. Business Philosophy Focus	13	12	10/16	9/17
I.2. Organizational Factors	9	11	7/13	8/15
I.3. Supplier Capabilities	8	9	6/10	6/9
II.1. Impact of Design Methods	8	9	6/11	5/12
II.2. Design Tools	9	10	8/10	8/11
II.3. Design Criteria	15	13	12/17	8/17
III.1. Communication Methods	15	18	10/23	14/21
III.2. Organizational & HR Management Factors	10	12	9/12	10/16

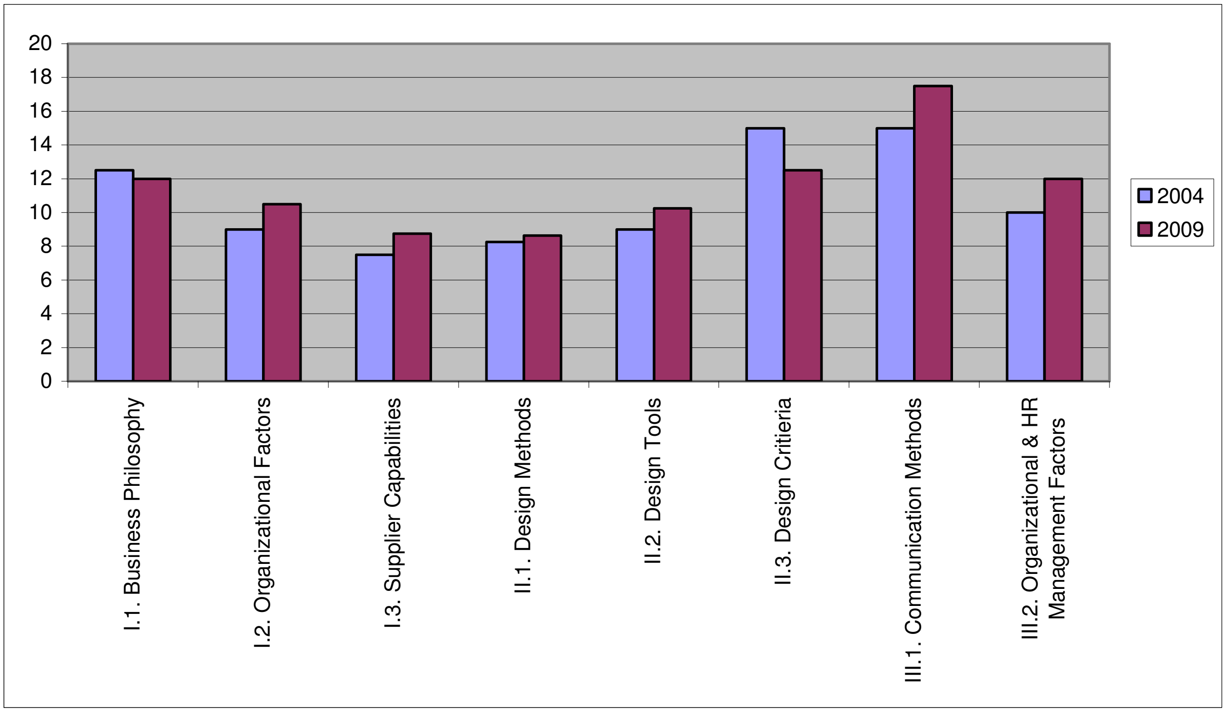


Figure 3. Median Trends of Weighted Questions.

Discussion and Strategic Considerations:

The two major issues now and in the future are forecasted to be communication and design criteria. However, while the communication issue will become increasingly important─eclipsing all other issues─design criteria will become less important, tying for second place with business philosophy and HR management. Organizational factors, design tools, design methods and supplier capabilities have a lower impact on product development success.

The increase in communication is even more impressive when one examines the IQR scores. Currently the panel is the most divided on the importance of communication methods: 50% of the panel rank communication between 10 and 23. The panel is more in agreement in its opinion of the future where 50% of the panel ranks the importance of communication methods between 14 and 21.

Panelists generally agree on the importance of supplier capabilities and design tools, both now and in the future. The future is less clear in the areas of design criteria, business philosophy, organizational factors, and HR management─all showing the largest IQR scores.

It is interesting to note that the issues typically associated with product design, namely design methods and tools and suppliers, are the issues that have the least impact on product development success. Conversely, communication, design criteria, business philosophy, and HR management are viewed as the most important factors both now and in the future. We believe this reflects the nature of modern product development: computer aided design tools have enabled broad systemization of the rudimentary product design tasks. This systemization has raised the importance of proper decision making to meet design criteria through good communication methods between organizationally and geographically dispersed stakeholders, a proper business philosophy regarding the product, and technically competent designers (HR management).

III.3. Overall Weighted Factor Comparison

Panelists were asked to rate the relative importance of 78 different factors. These factors were broken down into 8 questions within 3 categories. Some of these questions were further divided into different vehicle areas (interiors, powertrain, and body) as well as communication channels, (within the organization, with suppliers, and with customers). This breakdown resulted in 9 different scenarios, each comparing 78 factors.

This section presents the results of all the weighted factors for the 9 scenarios. The results of the 9 scenarios are very similar in many ways, but also have some distinct differences. For ease of reading, the scenarios will be presented in three subsections according to the communication channels. This subdivision was selected because the factors related to communication generally ranked higher than the factors related to design criteria. Hence, the greatest similarity between the scenarios was found within each of the communication channels, as opposed to within the vehicle system.

This section examines the relative importance of factors between questions. Since there are so many factors (many of which are approximately equal in importance), this section only focuses on those factors which rose to prominence, i.e., obtained a weighted value greater than 2. This limit was selected based on the factor values. The average factor weight is 1.3. Between 1.3 and 2 there are many factors that are important. Above a value of 2, however, a few factors appear to be quite important. The relative importance of these factors is discussed here.

The reader is encouraged to read the detailed question analysis that immediately follows this section. There the reader can learn more about each factor and its relative importance within each question. Appendix A presents the full results of all 78 weighted factors for all 9 scenarios.

III.3.a. Communication within the Organization

This section presents the results of comparing all study factors across all categories for the scenario involving communication within the organization. Within this scenario there are three sub-scenarios: the weighted factors involving the design criteria for interiors, the body and chassis/suspension, and the engine and transmission.

Discussion

Table 3 shows the median weighted scores for all three sub-scenarios as well as their 25th and 75th quartiles sorted by their current weighted scores in descending order. Figure 4, Figure 5, and Figure 6 show the trends for each of the three scenarios.

Clearly electronic communication is the most important factor and will continue to grow in importance across all vehicle systems. It is equally clear that face-to-face communication will decrease across all vehicle systems.

While product cost will decrease in importance (relative to other factors) for all vehicle systems, its relative importance is different depending on the system. It is second most important for engines, third for interiors, and sixth for bodies.

Product performance for engines is equally as important a design criterion as product cost.

Design for manufacturing and design for reliability are generally the third through fifth leading factors, and their relative importance is expected to remain unchanged in the future. One should note the relatively narrow range between the quartiles indicating general agreement among the panelists.

Investment in the business philosophy of increasing design discipline is important now, but will decrease in importance in the future.

The organizational management factor of all parties working effectively toward a common goal will become the second most important factor, after electronic communication. And, as one panelist pointed out, "*one could imply that these two factors are inescapably linked. Because parties must work together, the 'need' arises for the most effective and efficient communication methods*."

Table 3. Comparison of Weighted Factors by Vehicle System for the Communication within Organization Scenario.

System	Factor	Median		Quartile (25/75)	
		2004	2009	2004	2009
Interiors	Electronic communication (i.e., internet / email / ftp)	4.2	4.5	3.4/4.5	3.6/6.0
	Physical face-to-face meetings	3.0	2.0	1.9/4.8	1.4/3.5
	Final product cost	2.8	2.0	2.1/3.0	1.8/2.7
	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
Body	Electronic communication (i.e., internet / email / ftp)	4.2	4.5	3.4/4.5	3.6/6.0
	Physical face-to-face meetings	3.0	2.0	1.9/4.8	1.4/3.5
	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Final product cost	2.1	2.0	0.8/2.8	1.0/2.7
	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
Engine	Electronic communication (i.e., internet / email / ftp)	4.2	4.5	3.4/4.5	3.6/6.0
	Final product cost	3.4	2.5	2.3/3.9	1.8/3.6
	Product specific performance characteristics	3.2	2.6	2.2/4.0	1.9/3.7
	Physical face-to-face meetings	3.0	2.0	1.9/4.8	1.4/3.5
	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Product quality, reliability, and durability	2.0	1.7	1.7/2.9	1.1/2.2
	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0

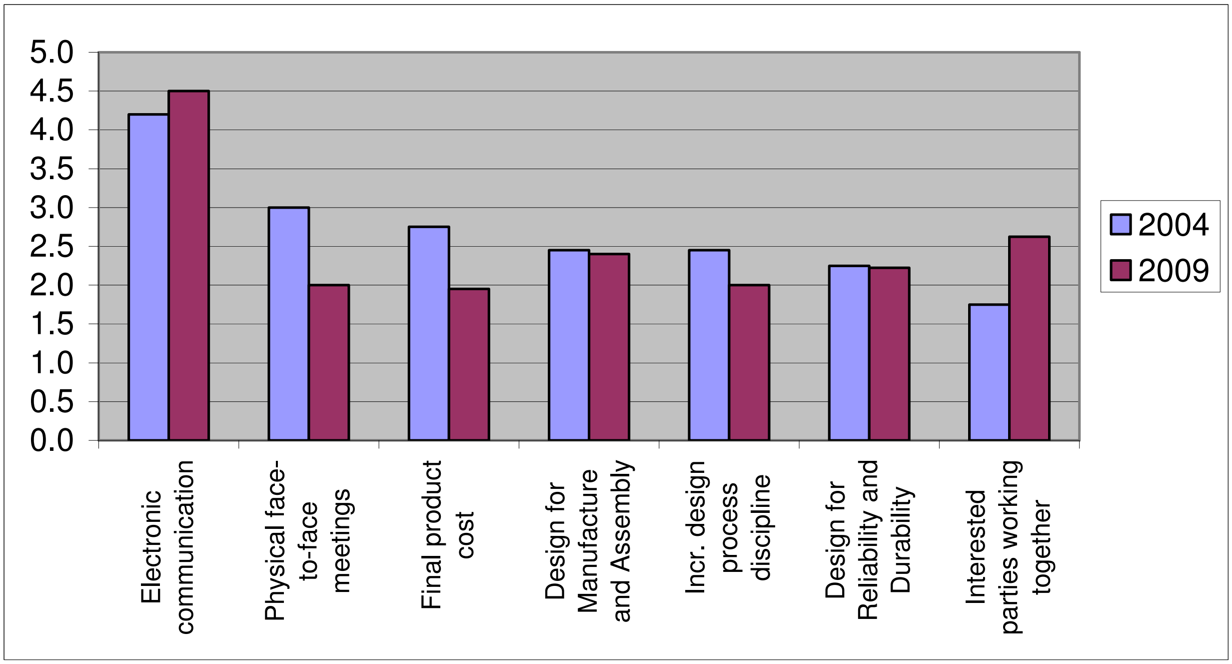


Figure 4. Median Trends of Weighted Factors across all Questions for the Scenario: Communication within the Organization and Interiors Design Criteria.

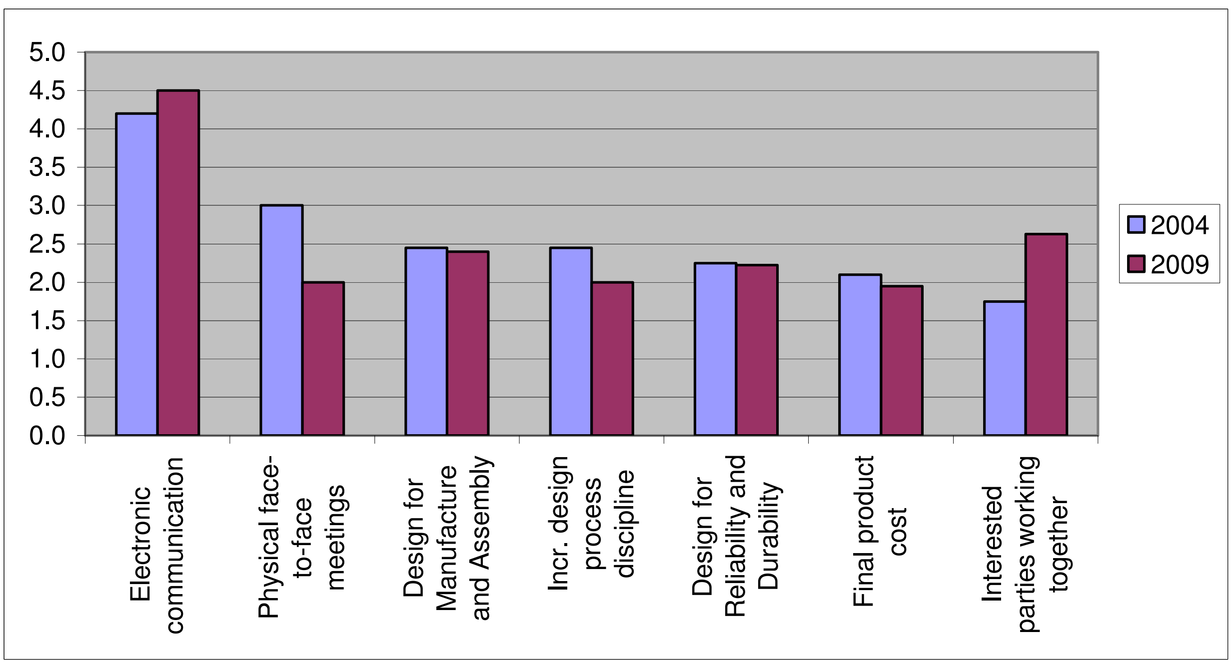


Figure 5. Median Trends of Weighted Factors across all Questions for the Scenario: Communication within the Organization and Body Design Criteria.

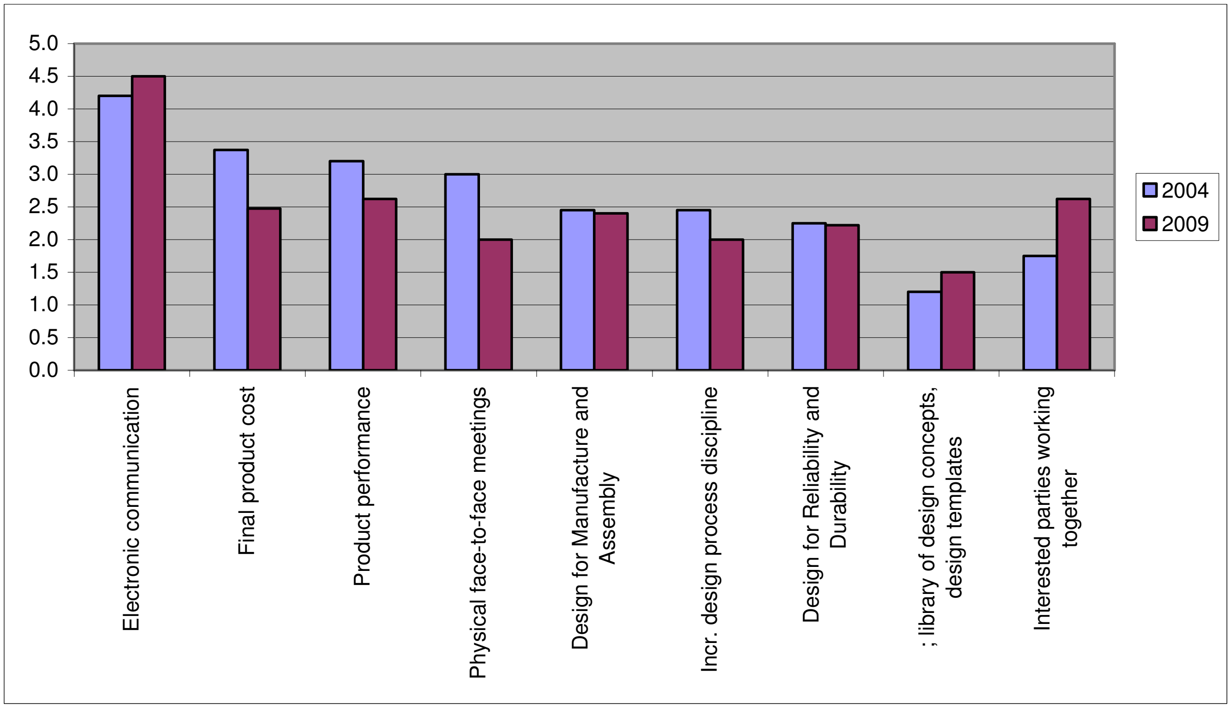


Figure 6. Median Trends of Weighted Factors across all Questions for the Scenario: Communication within the Organization and Engine Design Criteria.

III.3.b. Communication with Suppliers

This section presents the results of comparing all study factors across all categories for the scenario involving communication with suppliers. Within this scenario there are three sub-scenarios: the weighted factors involving the design criteria for interiors, the body and chassis/suspension, and the engine and transmission.

Discussion

Table 4 shows the median weighted scores for all three sub-scenarios as well as their 25th and 75th quartiles sorted by their current weighted scores in descending order. Figure 7, Figure 8, and Figure 9 show the trends for each of the three scenarios.

It is interesting to note that of the most important factors, almost half are communication methods. And every one of them is expected to decrease in importance relative to other factors. That is not to say that supplier communication will not remain important, but that as supplier communication improves, other factors gain in relative importance. Clearly electronic communication is the most important factor, and will remain so in the future, albeit with a slight decline. Also, while the median decreases, both quartiles increase, suggesting that the decrease in the median is not significant.

While face-to-face communication was deemed important within an organization, voice mail and fax are the 2nd to 4th most important communication methods with suppliers in achieving an effective product design. Noteworthy too is the appearance of print based communication, although its current importance is just below face-to-face communication. Both of these communication channels are expected to drop to or below the 2.0 threshold, although the panel is not in agreement over the drop in voice mail and fax communication as evidenced by the large IQR.

In general, the graphs for interiors and bodies appear very similar. While product cost will decrease in importance relative to other factors for all vehicle systems, its relative importance to other factors is different depending on the system. It is second most important for interiors and engines, and seventh for bodies. Accordingly, its expected future decline is quite great for interiors and engines, but less so for bodies. The panel was in general agreement regarding the drop on interiors, but less so for engines.

The graph for engines is notably different, in that product performance is much more important than for the other systems. It is the third most important factor for engines and does not show up at all in the other systems. While its importance is expected to decline in the future, it remains one of the most important factors for engine design.

Design for manufacturing and design for reliability are generally the fifth through seventh leading factors and their relative importance is expected to remain unchanged in the future. One should note the relatively narrow range between the quartiles indicating general agreement among the panelists.

Investment in the business philosophy of increasing design discipline is relatively important now, but will decrease in importance in the future.

The organizational management factor of all parties working effectively toward a common goal becomes the second most important factor in the future after electronic communication. And, as one panelist pointed out, "*one could imply that these two factors are inescapably linked. Because parties must work together, the "need" arises for the most effective and efficient communication methods*."

Table 4. Comparison of Weighted Factors by Vehicle System for the Communication with Suppliers Scenario

System	Factor	Median		Quartile (25/75)	
		2004	2009	2004	2009
Interiors	Electronic communication (i.e., internet / email / ftp)	4.2	3.8	2.8/6.3	3.1/7.2
	Final product cost	2.8	2.0	2.1/3.0	1.8/2.7
	Voice mail and fax	2.5	2.0	1.3/2.9	1.3/3.1
	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Physical face-to-face meetings	2.3	2.1	2.1/3.6	1.5/2.8
	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.1	1.5	0.7/3.4	0.5/2.0
	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
Body	Electronic communication (i.e., internet / email / ftp)	4.2	3.8	2.8/6.3	3.1/7.2
	Voice mail and fax	2.5	2.0	1.3/2.9	1.3/3.1
	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Physical face-to-face meetings	2.3	2.1	2.1/3.6	1.5/2.8
	Final product cost	2.1	2.0	0.8/2.8	1.0/2.7
	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.1	1.5	0.7/3.4	0.5/2.0
	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
Engine	Electronic communication (i.e., internet / email / ftp)	4.2	3.8	2.8/6.3	3.1/7.2
	Final product cost	3.4	2.5	2.3/3.9	1.8/3.6
	Product specific performance characteristics	3.2	2.6	2.2/4.0	1.9/3.7
	Voice mail and fax	2.5	2.0	1.3/2.9	1.3/3.1
	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Physical face-to-face meetings	2.3	2.1	2.1/3.6	1.5/2.8
	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.1	1.5	0.7/3.4	0.5/2.0
	Product quality, reliability, and durability	2.0	1.7	1.7/2.9	1.1/2.2
	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0

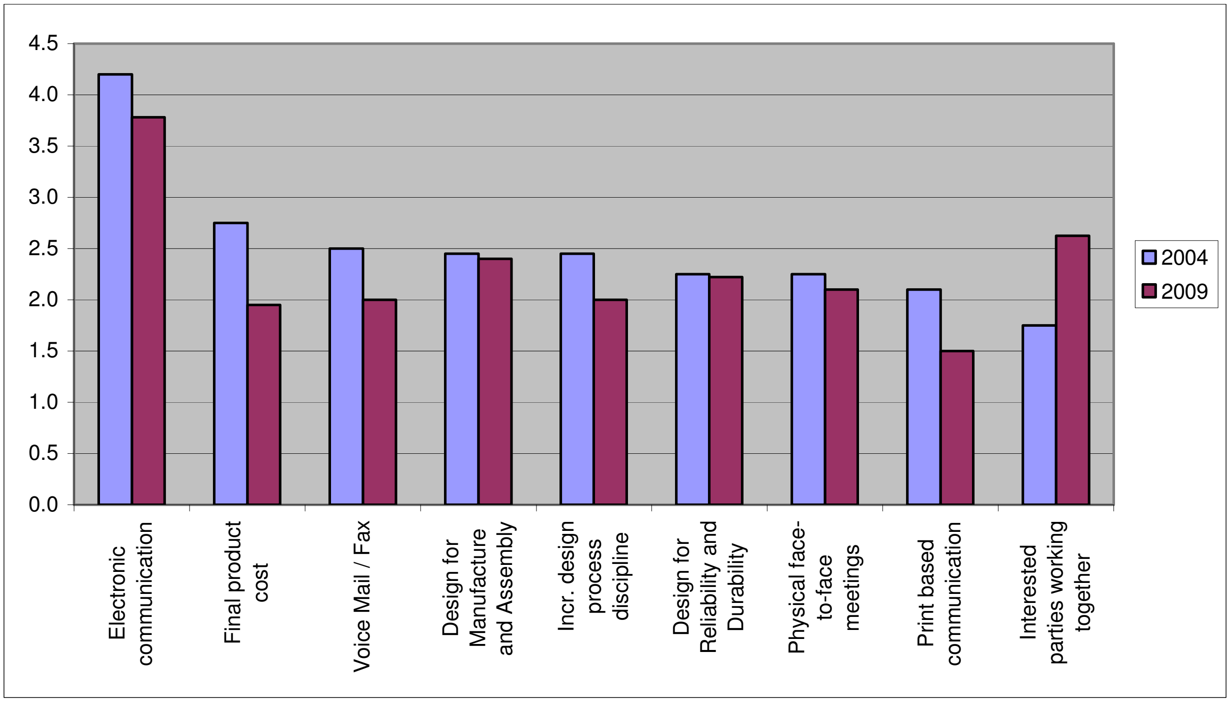


Figure 7. Median Trends of Weighted Factors across all Questions for the Scenario: Communication with Suppliers and Interior Design Criteria.

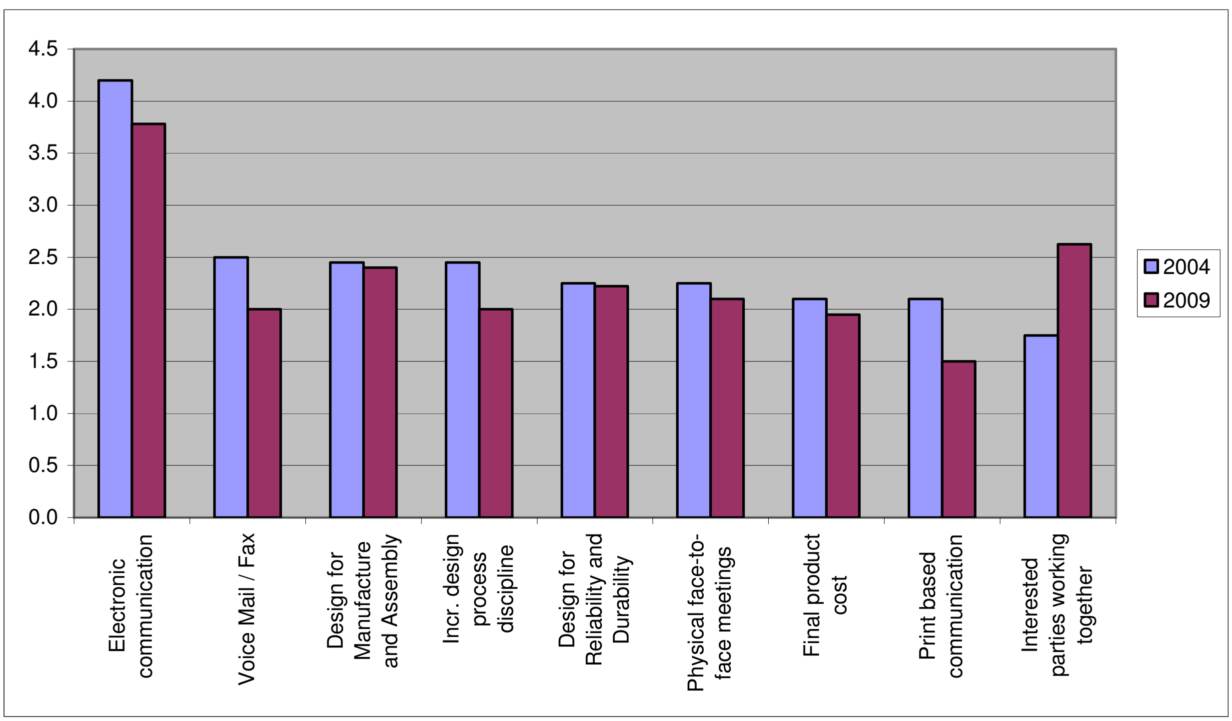


Figure 8. Median Trends of Weighted Factors across all Questions for the Scenario: Communication with Suppliers and Body Design Criteria.

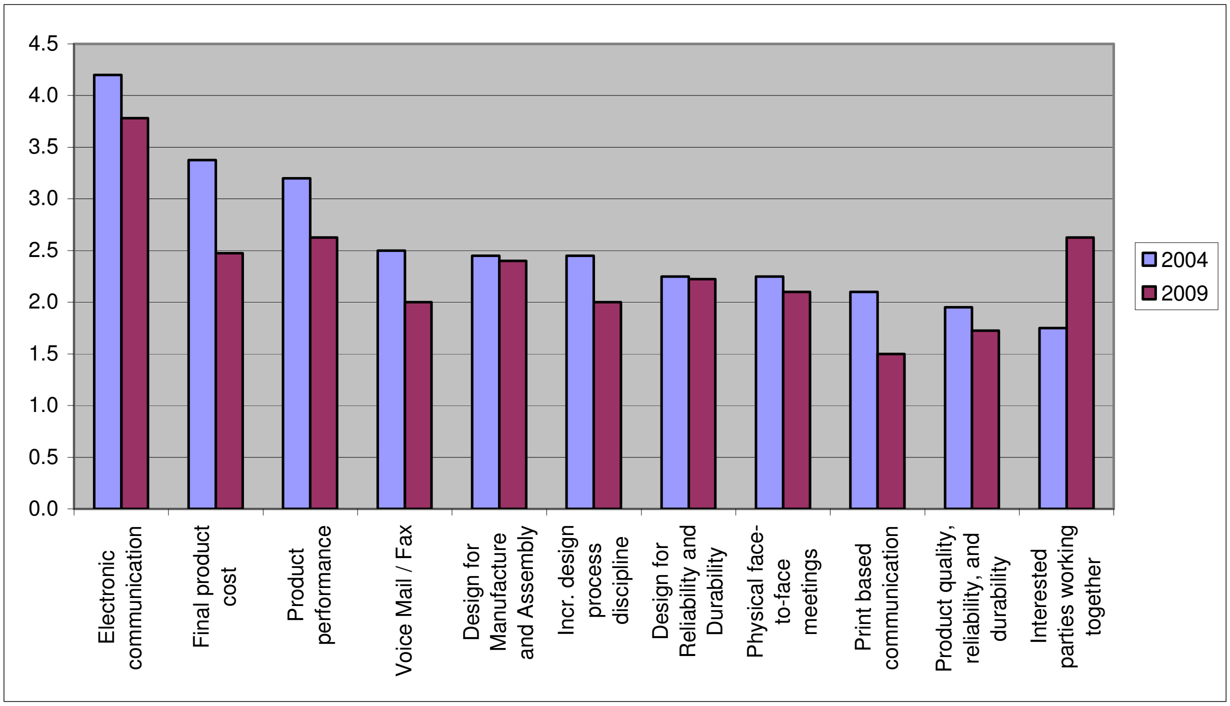


Figure 9. Median Trends of Weighted Factors across all Questions for the Scenario: Communication with Suppliers and Engine Design Criteria.

III.3.c. Communication with Customers

This section presents the results of comparing all study factors across all categories for the scenario involving communication with customers. Within this scenario there are three sub-scenarios: the weighted factors involving the design criteria for interiors, the body and chassis/suspension, and the engine and transmission.

Discussion

Table 5 shows the median weighted scores for all three sub-scenarios as well as their 25th and 75th quartiles sorted by their current weighted scores in descending order. Figure 10, Figure 11, and Figure 12 show the trends for each of the three scenarios.

Clearly, electronic communication is the most important factor and will continue to grow in importance across all vehicle systems. It is equally clear that face-to-face communication (the second most important factor for interiors and bodies and fourth for engines) will decrease across all vehicle systems. Print-based communication is much more important when communicating with customers than within the organization or with suppliers. But, this is expected to change in the future, with a dramatic reduction in its importance.

In general, the graphs for interiors and bodies appear very similar. While product cost will decrease in importance relative to other factors for all vehicle systems, its relative importance to other factors is different depending on the system. It is second most important for engines, third for interiors, and seventh for bodies. Accordingly, its expected future decline is quite great for interiors and engines, but less so for bodies. The panel was also in general agreement regarding the drop on interiors, but less so for engines.

The graph for engines is notably different in that product performance is much more important than for the other systems. It is the third most important factor for engines and does not show up at all in the other systems. While its importance is expected to decline in the future it remains one of the most important factors for engine design.

Design for manufacturing and design for reliability are generally the third through fifth and fifth through seventh leading factors respectively. Their relative importance is expected to remain unchanged in the future. One should note the relatively narrow range between the quartiles, indicating general agreement among the panelists.

Investment in the business philosophy of increasing design discipline is important now, but will decrease in importance in the future.

The organizational management factor of all parties working effectively towards a common goal becomes the second most important factor in the future after electronic communication. And, as one panelist pointed out, "*one could imply that these two factors are inescapably linked. Because parties must work together, the "need" arises for the most effective and efficient communication methods*."

Table 5. Comparison of Weighted Factors by Vehicle System for the Communication with Customers Scenario

System	Factor	Median		Quartile (25/75)	
		2004	2009	2004	2009
Interiors	Electronic communication (i.e., internet / email / ftp)	4.2	4.4	3.8/6.0	3.2/8.0
	Physical face-to-face meetings	2.8	2.0	2.1/3.2	1.4/3.2
	Final product cost	2.8	2.0	2.1/3.0	1.8/2.7
	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.6	0.8	0.8/3.6	0.3/1.8
	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
Body	Electronic communication (i.e., internet / email / ftp)	4.2	4.4	3.8/6.0	3.2/8.0
	Physical face-to-face meetings	2.8	2.0	2.1/3.2	1.4/3.2
	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.6	0.8	0.8/3.6	0.3/1.8
	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Final product cost	2.1	2.0	0.8/2.8	1.0/2.7
	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
Engine	Electronic communication (i.e., internet / email / ftp)	4.2	4.4	3.8/6.0	3.2/8.0
	Final product cost	3.4	2.5	2.3/3.9	1.8/3.6
	Product specific performance characteristics	3.2	2.6	2.2/4.0	1.9/3.7
	Physical face-to-face meetings	2.8	2.0	2.1/3.2	1.4/3.2
	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.6	0.8	0.8/3.6	0.3/1.8
	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Product quality, reliability, and durability	2.0	1.7	1.7/2.9	1.1/2.2
	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0

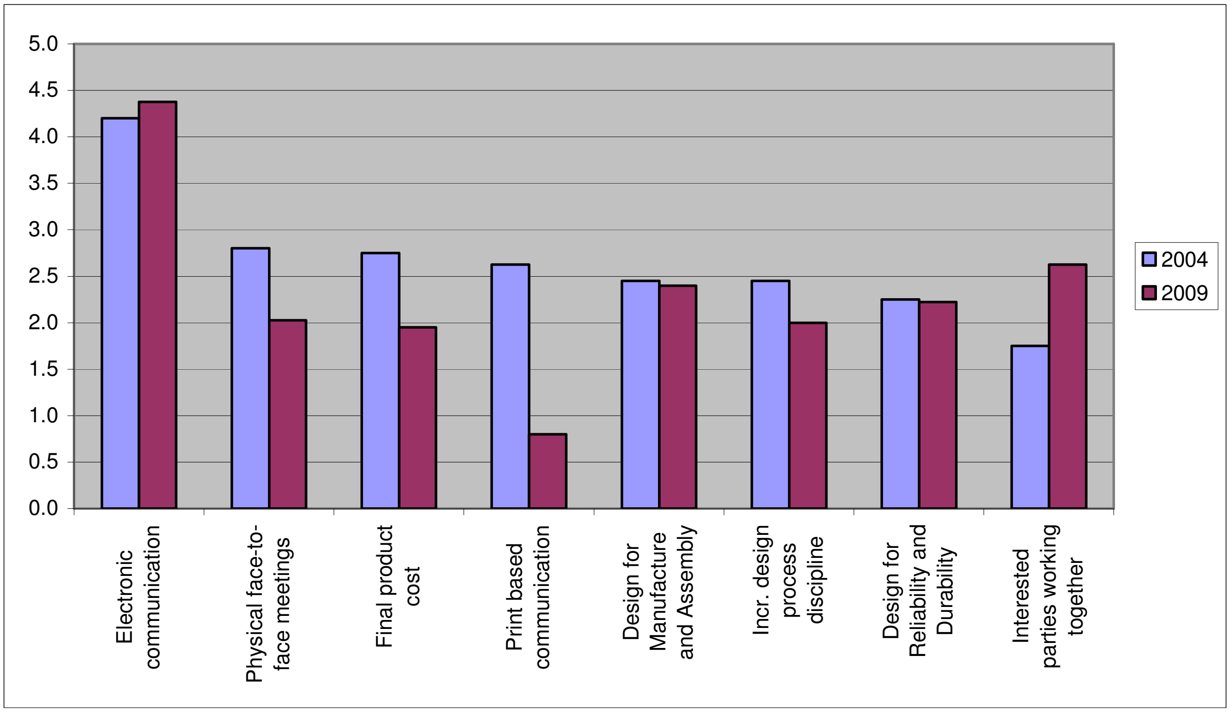


Figure 10. Median Trends of Weighted Factors across all Questions for the Scenario: Communication with Customers and Interior Design Criteria.

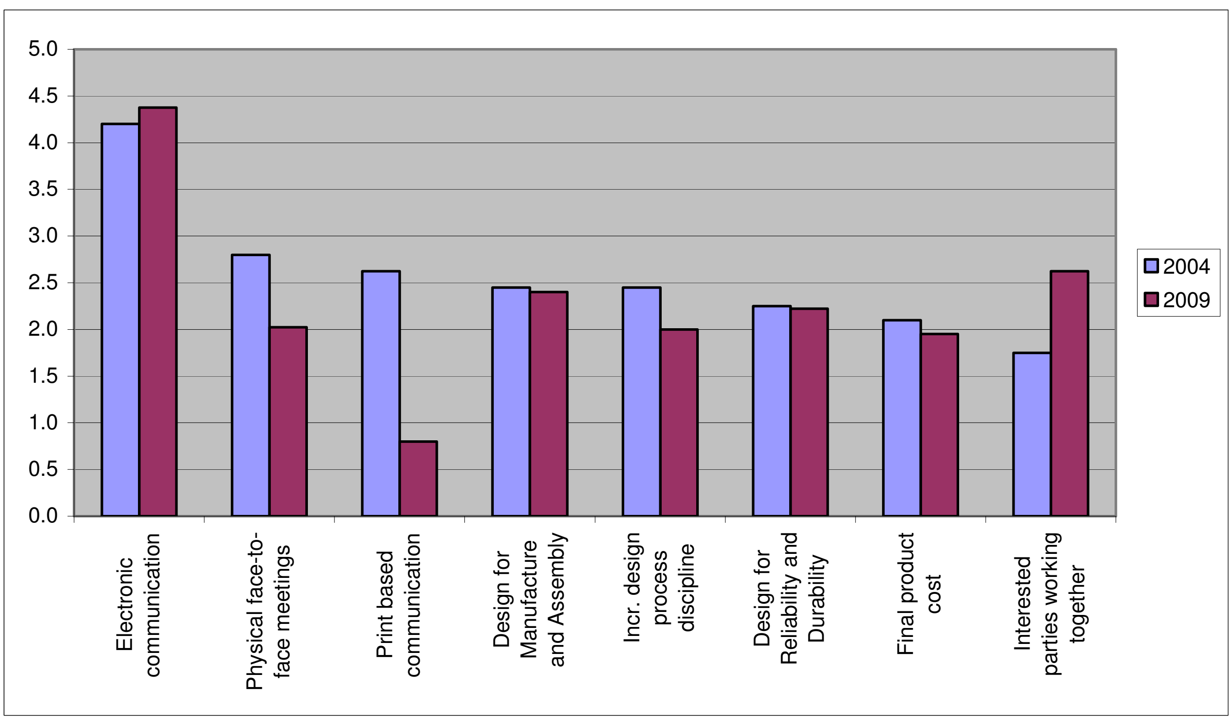


Figure 11. Median Trends of Weighted Factors across all Questions for the Scenario: Communication with Customers and Body Design Criteria.

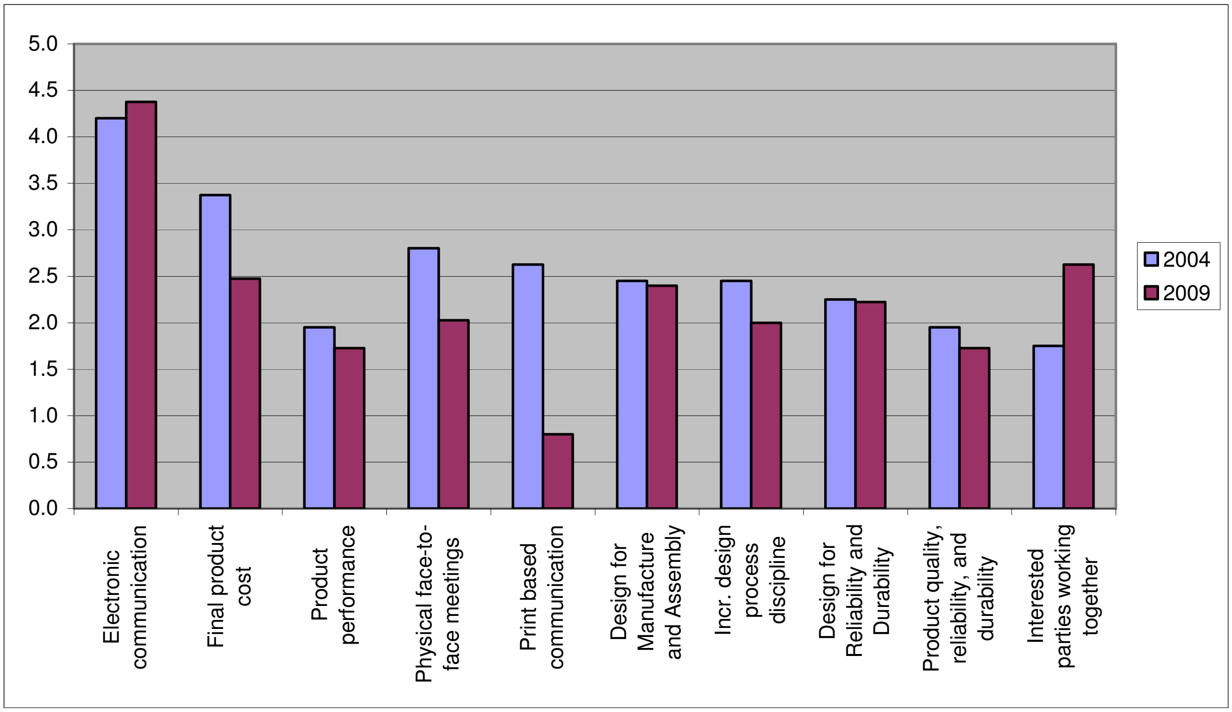


Figure 12. Median Trends of Weighted Factors across all Questions for the Scenario: Communication with Customers and Engine Design Criteria.

Strategic Considerations

Clearly, increasing the speed of decision making is now and for the foreseeable future the most important goal. Electronic communication and a disciplined product development process support this goal. And as the decision making requires input from groups that are often separated by function and geography, traditional forms of communication—face-to-face, voice mail (with suppliers), and print-based (with customers)—will become less and less the methods of choice. While the speed of communication increases, thereby helping decision making, so too must the speed of execution increase in the future. The panel believes that this will require organizations to shift their management focus to ensuring that all parties work effectively toward a common goal.

Designing products that can be manufactured and that have good quality and reliability will always be of prime importance. With regard to interiors and the body, design is even more important than the product specific performance measures, and in the case of the body, more important than cost (although cost and manufacturability are directly related). With regard to engines, product cost and product performance are currently the second and third most important factors after electronic communication. And they will remain so in the future in conjunction with all parties working together effectively. Clearly, with regard to engines, the panel does not expect major shifts in future product design priorities.

IV. Business Philosophy, Organizational Factors and Supplier Capabilities

This section covers the individual questions asked in the business philosophy, organizational factors, and supplier capabilities category. Again the analysis is based on the weighted responses. Thus, every response here can be compared on the same scale with every other response in the weighted analysis section. This means that, while the instructions asked the panelist to distribute 100 points across the question, the response was multiplied by the relative weights for the question. Thus, the reported median scores will not sum to 100 within the questions.

Two benchmarks are the following. First, the average weighted score is approximately 1.3. Thus, any score that ranks above a 1.3 is an above average score. Second, those factors scoring a 2 or higher rose to prominence above all other factors (see Section III.3. Overall Weighted Factor Comparison).

IV.1.Business Philosophy Focus

Please prioritize which business philosophies your company is currently focused upon (expending resources to implement) and will be focusing upon in the future by distributing 100 points to each column.

Table 6. Median and Quartile scores for Business Philosophy Focus.

Business Philosophy	**Median**		**Quartile (25/75)**	
	2004	**2009**	**2004**	**2009**
Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1

Selected Edited Comments:

- Other strategies: Cost control, product leadership.
- The key here is to focus on value leadership and continually tradeoff/flex the [product] function and cost relationship depending on the customer requirement / business circumstances. An ability to create and produce a product that provides a distinctive functional benefit vs. the competition. The combination of functional characteristics relative to commercial characteristics leads to a value leadership quotient which may turn out to be a more important discriminator in real world business decisions than does product leadership.
- Establish and implement engineering competencies globally to remain competitive. Our company will continue to increase/focus on design re-use strategies.

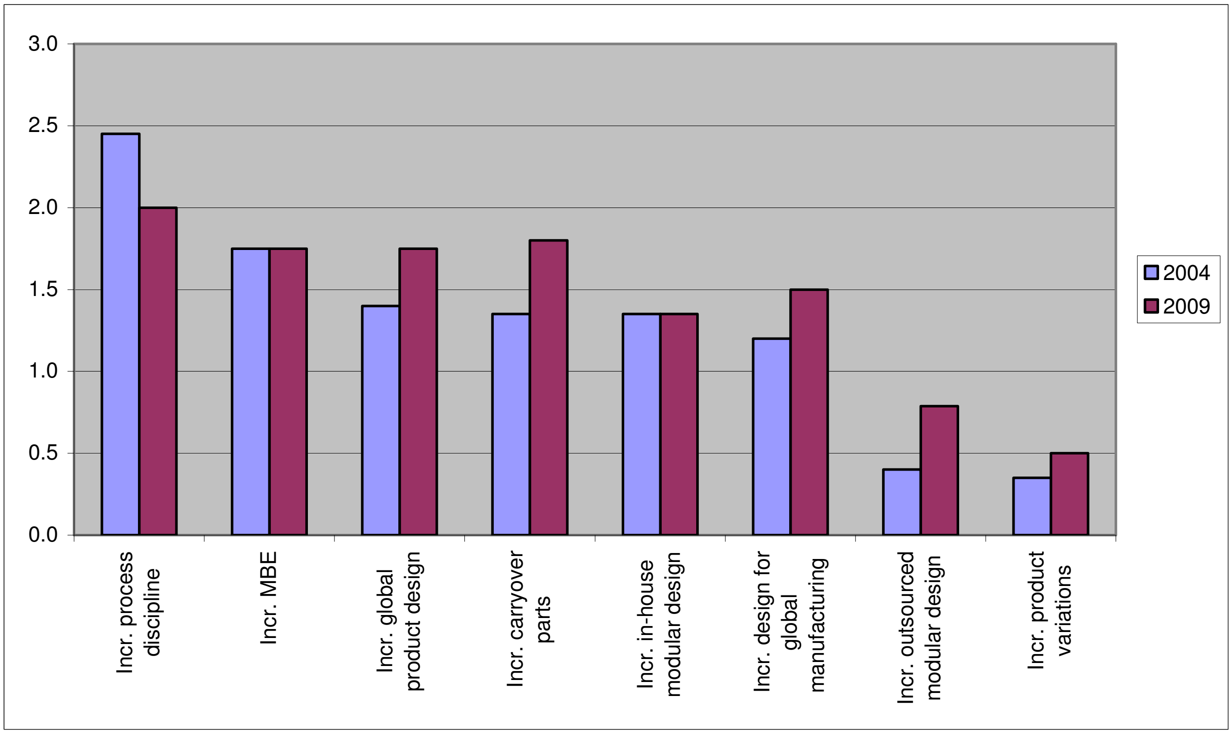


Figure 13. Median trends in Business Philosophy Focus for 2004 and 2009.

Discussion and Strategic Considerations:
First, with the exception of increasing product variation and increasing outsourcing of modular designs, all other business strategies ranked at or above the average weighted score of 1.3, indicating that business strategies are important. However, the only strategy to rank above a 2.0, and thereby show up as an important factor relative to the other factors in the study, was increasing process design discipline (see section III.3. Overall Weighted Factor Comparison).

Figure 13 shows three groups of strategies: those with relatively high priority, namely Increasing Design Process Discipline and Increasing Math Based Engineering (MBE); those with relatively low priority, namely increasing outsourcing and increasing product design variation; and those with moderate priority, namely the remaining strategies.

Based on the median responses, the respondents expect almost all of these strategies to gain in importance, except increasing process discipline. In addition, increasing modular design has a flat trajectory. The fact that design process discipline is decreasing in importance should not be interpreted as the philosophy becoming less important. Rather, it indicates that as the process discipline takes hold in a company, fewer resources will be needed to improve process discipline, and resources can be expended on improving other strategic issues. Further, this factor ranked above a 2.0 for 2004 and is expected to drop to a 2.0 in 2009. This implies it will remain the most important Business Philosophy and one of the most important overall product design factors into the future.

Comparing the quartiles scores is illuminating. First, the greatest spread in the quartiles is for increasing Design Process Discipline. Its current 25th percentile score is 1 and its 75th percentile score is 3.5 resulting in an inter-quartile range (IQR) of 2.5. This factor changes in the future where it has the lowest IQR. This means that, while the panelists differ significantly as to the current importance of increasing process discipline relative to other strategies, they are nearly unanimous as to its importance in the future. However, it should be noted that the IQR for all responses in this category is quite high. Hence, one can conclude that there is no consensus with regard to business strategies. This is also evident in the panelists' comments. One panelist suggests focusing on cost control and product leadership, another suggests value leadership over product leadership, and yet another suggests engineering competence and design re-use.

The overall conclusion is that different companies are pursuing different strategies, and there is no consensus as to their relative importance or which are going to be successful.

IV.2.Impact of Organizational Factors

Please prioritize which Organizational Factors your company is currently focused upon (expending resources to implement) and will be focusing upon in the future by distributing 100 points to each column.

Table 7. Median and Quartile Scores for Impact of Organizational Factors.

Organizational Factors	**Median**		**Quartile (25/75)**	
	2004	**2009**	**2004**	**2009**
Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2

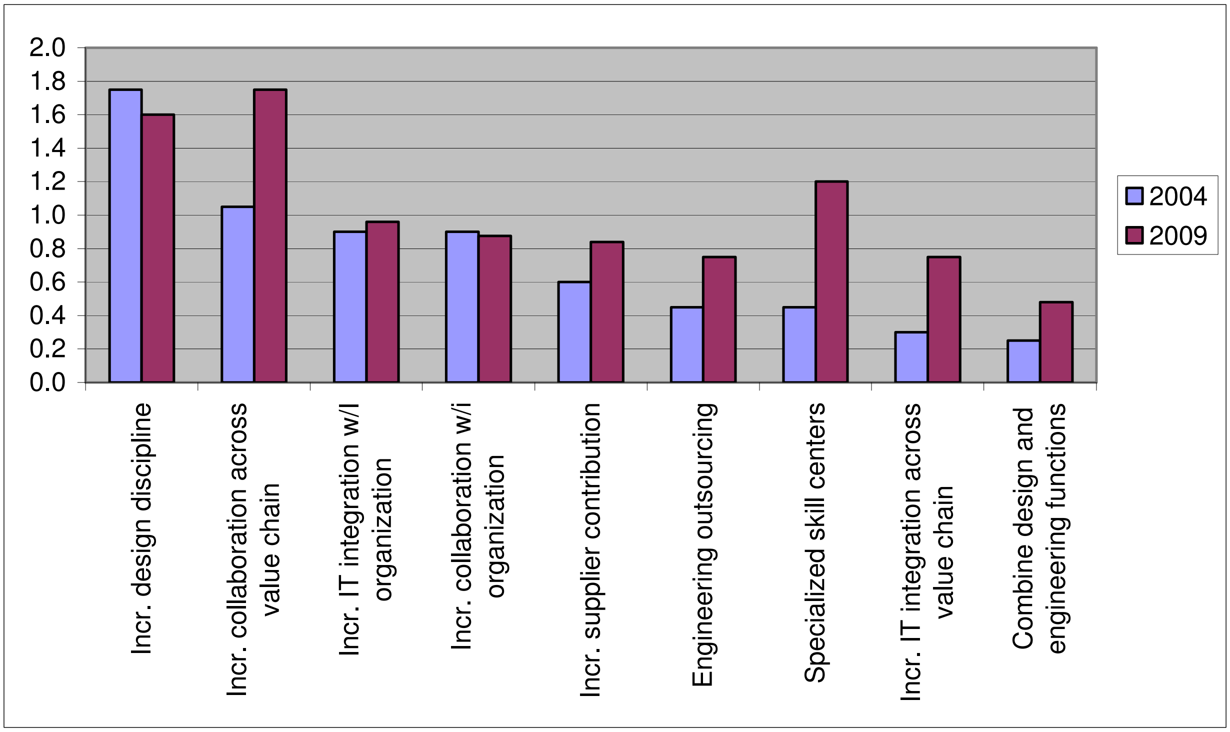


Figure 14. Median Trends of Organizational Factors

Selected Edited Comments:

- We need to continue refining and improving the engineering process to take time out and improve robustness of design.

Discussion and Strategic Considerations:

In general, Organizational Factors have a low impact on product design success. With the exception of increasing product design discipline, none of the organizational factors ranked above the average 1.3. And with the further exception of increasing collaboration across the supply chain, none will in the future.

The panel agreed (low IQR of 0.3) that companies are currently focusing more on increasing design discipline than any other organizational factor, a consensus reinforced by a panelist's comment. While this focus is predicted to decline slightly, the increased IQR makes the decline insignificant.

There is relative concurrence on the need to increase collaboration across the supply chain. This need is expected to gain in importance in the future, becoming the most important factor.

Another major factor that will have a great impact in the future is the creation and utilization of specialized skill sets within the broader organization. Related to these last two is the increased supplier contribution to development work and increased outsourcing of engineering work, even though their priority is relatively low. As more engineering work is outsourced and suppliers contribute more to the product design process, the need for greater collaboration with supply chain increases. Further, the increased outsourcing will necessitate more efficient use and development of specialized skill sets within the organization to develop and retain the organization's core competencies.

The trends are clear. The supply base will continue to gain in prominence as it develops specialized expertise to meet the increased engineering development demands placed on it by its customers. This trend also increases the need for improved collaboration and some improvement in the integration of computer systems across the entire value chain. The integration of computer systems within an organization will continue to consume resources, but not at an increased pace.

The relative strengths of these various factors are linked with the perceived resources needed to ensure proper product development success. The simple outsourcing of engineering requires relatively little effort, compared to collaboration with those same suppliers. This outsourcing trend is seen as a theme throughout the survey and is explored in Section 0. Design also has difficulty when sales and marketing promise customers too much, be it in product features or delivery times. There was a suggestion to implement a more accurate quoting system. But, there are other issues as well, such as a better understanding of customer's needs earlier in the design phase. Also, once the design cycle has begun, certain customer desires may be difficult to implement. Thus, managing the customer's expectations and providing the communication between the customer and design, becomes critical.

Clearly as the speed to deliver timely information across the globe and organizational boundaries increases, so does our ability and desire to make effective decisions quickly. These changes show everyone where the gaps in human understanding and communication between the various functions in the value chain lie. It is hoped that this study will shed some light on this important topic and encourage discussion within the industry.

Allocation of Developmental Resources.

IV.3. Impact of Supplier Capabilities

Please prioritize which Supplier Capabilities your company is currently focusing upon and will be focusing upon in the future in supplier selection by distributing 100 points to each column.

Table 8. Median and Quartile Scores for Supplier Capabilities.

Supplier Capabilities	**Median**		**Quartile (25/75)**	
	2004	**2009**	**2004**	**2009**
Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3
Systems integration capabilities (system interaction expertise, full service support, "black box" capability)	0.0	0.1	0.0/0.9	0.0/0.8
Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Proximity of supplier plant to our plant (within ½ day travel)	0.0	0.0	0.0/0.4	0.0/0.4
Rapid prototyping capabilities	0.0	0.0	0.0/0.5	0.0/0.5

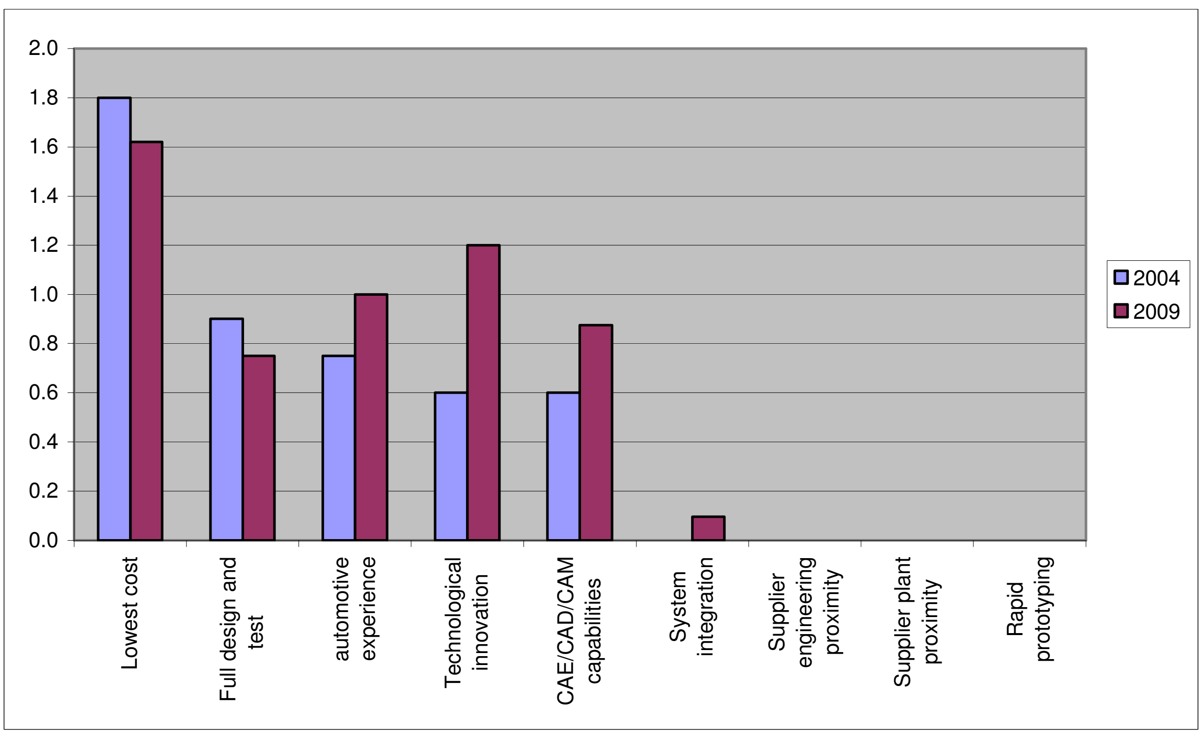


Figure 15. Median Trends of Supplier Capabilities.

Discussion and Strategic Considerations:
Not surprisingly, providing the lowest cost product or service is of the greatest importance. However, the panel was very divided on this issue, as evidenced by the large IQR. While this factor had the highest median score, it also had the highest IQR. This IQR becomes significantly narrower in the future, meaning that the majority of the panel believes it will have a lower impact in the future. But, they also generally agree that, despite its decline in relative importance, it will still remain the most important factor. It was also the only factor to rank above the average 1.3 for all factors in the study. All other supplier factors are considered to be less important that half of the other factors in the study.

Factors expected to increase in importance in supplier selection are experience and technical innovation, whereas factors that are expected to have a decreasing impact are a supplier's design and testing capability and their CAD/CAM capabilities. But, again, there was significant variation between the panelists on this issue.

While there was less agreement on what was important, there was a fair degree of agreement on what was not important, such as the proximity of the supplier's engineering and manufacturing facilities to the customer─defined as a half day of travel. In addition, systems integration and rapid prototyping capabilities were not considered important.

The continued emphasis on cost is not surprising given the predicted trend in outsourcing. However, there are clearly some who expect the cost factor to have a decreasing influence with increased collaboration. As cost becomes less important, outsourcing to suppliers continues, and collaboration increases, technical innovation and supplier experience become more important factors.

It is interesting to note the consensus on those factors that do not have any impact on supplier selection, namely the proximity of the supplier to the customer, systems integration and rapid prototyping capability. The fact that proximity to customer has no impact is possibly a reflection of the global sourcing that is so prevalent today and is only expected to increase in the future (see Section 0. Design also has difficulty when sales and marketing promise customers too much, be it in product features or delivery times. There was a suggestion to implement a more accurate quoting system. But, there are other issues as well, such as a better understanding of customer's needs earlier in the design phase. Also, once the design cycle has begun, certain customer desires may be difficult to implement. Thus, managing the customer's expectations and providing the communication between the customer and design, becomes critical.

Clearly as the speed to deliver timely information across the globe and organizational boundaries increases, so does our ability and desire to make effective decisions quickly. These changes show everyone where the gaps in human understanding and communication between the various functions in the value chain lie. It is hoped that this study will shed some light on this important topic and encourage discussion within the industry.

Allocation of Developmental Resources).

With regard to rapid prototyping and systems integration, the panel either believes these are skills their customers are retaining, or they are skills all suppliers are expected to have (and hence are not skills that will differentiate one supplier from another), or these skills will be replaced by simulation and other tools that forego the need for physical prototypes. In Section V. Design Methods, Tools, and Criteria there is evidence to support this latter interpretation.

V. Design Methods, Tools, and Criteria

This section covers the individual questions asked in the design methods, tools and criteria category. One might think of this area as the core of product design. Again, the analysis is based on the weighted responses. Every response here can be compared on the same scale with every other response in the weighted analysis section. This means that, while the instructions asked the panelist to distribute 100 points across the question, the response was multiplied by the relative weights for the question. Thus, the reported median scores will not sum to 100 within the questions.

Two benchmarks are the following. First, the average weighted score is approximately 1.3. Thus, any score that ranks above a 1.3 is an above average weight. Second, those factors scoring a 2 or higher rose to prominence above all other factors (see Section III.3. Overall Weighted Factor Comparison).

V.1. Impact of Design Methods

Please prioritize the current and future influence of each of the following Design Methods on your company's product design and development success by distributing 100 points in each column.

Table 9. Median and Quartile Scores for Design Methods.

Design Method	Median		Quartile (25/75)	
	2004	2009	2004	2009
Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7

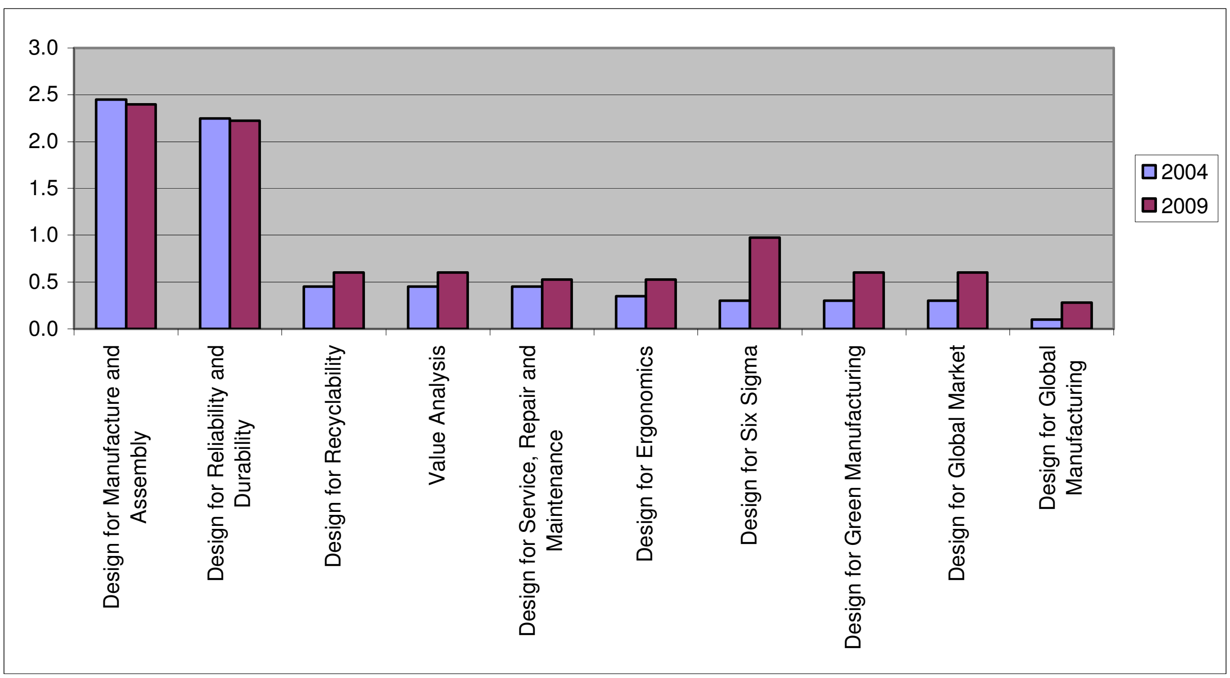


Figure 16. Median Trends for Design Methods.

Select Edited Comments:

- Past experience.
- DFMA and reliability are foremost.

Discussion and Strategic Considerations:
Clearly the two most important design methods used in 2004 and into the future are design for manufacturability and design for reliability, which is echoed by a panelist's comment. While design for six sigma shows the greatest gain, it also has the greatest IQR. This indicates that some panelists feel strongly about this methodology, while other panelists do not.

One cannot overemphasize the difference between the top two strategies and the rest. The gap is tremendous. The top two strategies are above average relative to all other factors in the study (score > 1.3) and score well above a 2.0 indicating that they are among the highest scoring factors. In contrast, all other design methodologies score well below the average score of 1.3. Even the methodology with the greatest gain only rises to a score of 1.0.

Design for manufacturability (DFM) continues to be the most important design method, as it was in the previous study five years ago. One might question the importance of DFM given the continuing trend to move manufacturing off-shore to lower-cost labor countries (see 0. Design also has difficulty when sales and marketing promise customers too much, be it in product features or delivery times. There was a suggestion to implement a more accurate quoting system. But, there are other issues as well, such as a better understanding of customer's needs earlier in the design phase. Also, once the design cycle has begun, certain customer desires may be difficult to implement. Thus, managing the customer's expectations and providing the communication between the customer and design, becomes critical.

Clearly as the speed to deliver timely information across the globe and organizational boundaries increases, so does our ability and desire to make effective decisions quickly. These changes show everyone where the gaps in human understanding and communication between the various functions in the value chain lie. It is hoped that this study will shed some light on this important topic and encourage discussion within the industry.

Allocation of Developmental Resources). The argument is that, as labor costs shrink as a percent of the overall product cost, manufacturing would become less important. While this argument may apply in cases where automation could be replaced with manual labor (thus relieving design of the necessity to design for automation), it does not relieve design of its responsibility for a product that still can be manufactured. For example, product design must still create body styles that can be made by stamping steel without wrinkles or tears. Further, many of the lower labor cost countries may not always have the same skilled labor or infrastructure support that would be required from complex or advanced manufacturing approaches, thus necessitating a more thorough analysis of a product's manufacturability. Lastly, competitors can also move their manufacturing off-shore to gain the labor cost advantages. Thus, DFM as a method to reduce costs becomes more important.

Some changes to the current survey include the questions on global design and global manufacturing. While it was anticipated that these methods would rank higher, their low score might be explained as follows. Although global sourcing and manufacturing of products that are accepted globally continue to be a priority, many OEMs have handled this challenge in ways that have a relatively low impact on product design effectiveness. Some have a standardized global production system. Hence, their particular product design could practically be manufactured anywhere. Also, the move toward manufacturing flexibility has given designers relatively more freedom to design products that can be produced globally. Lastly, it is possible that since most products are designed with a manufacturing plant in mind, designers may be taking those issues into account. Others have purchased companies or created alliances with companies that enable platform sharing to deal with regional differences.

V.2. Impact of Design Tools

Please prioritize the current and future influence of each of the following Design Tools on your company's product design and development success by distributing 100 points in each column.

Table 10. Median and Quartile Scores for Design Tools.

General Design Tools	Median		Quartile (25/75)	
	2004	2009	2004	2009
Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
Clay models	0.0	0.0	0.1/0.9	0.3/1.1
Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0

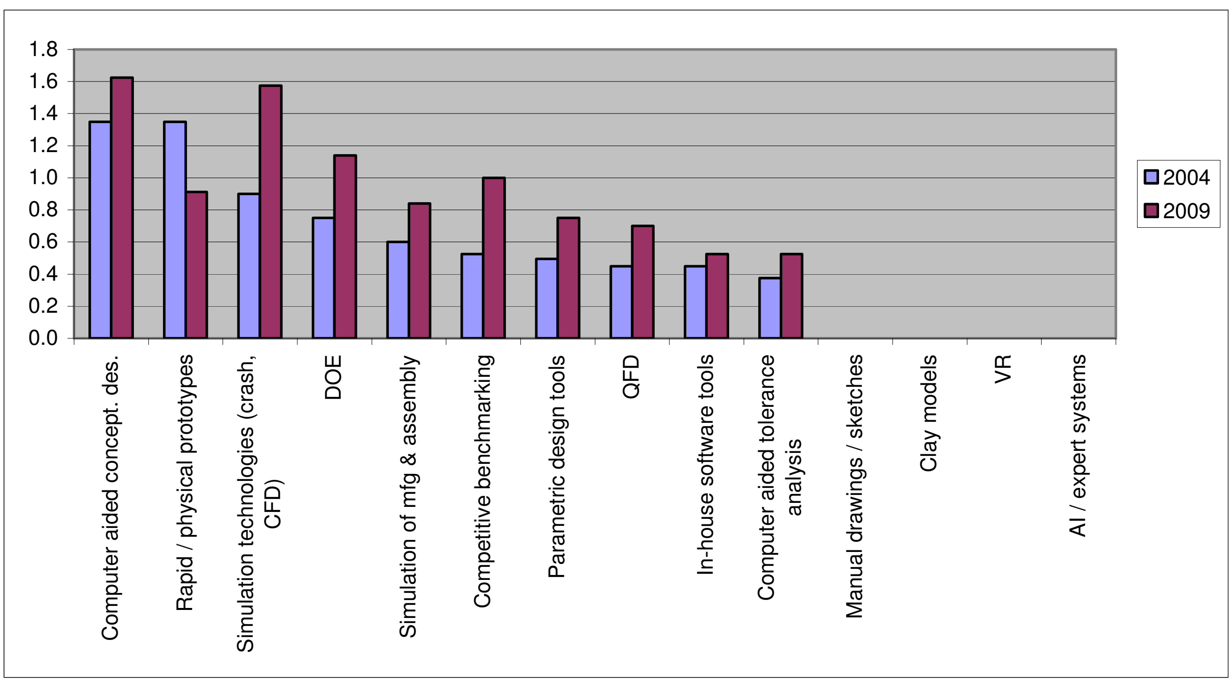


Figure 17. Median Trends for Design Tools.

Discussion and Strategic Considerations:
In general, all design tools with the notable exception of physical prototypes will gain in influence over the next 5 years. Currently, computer tools for conceptual design and rapid prototyping are the most influential tools used in product design, followed by product simulation technologies. However, within 5 years, the computer-based tools are expected to completely eclipse the need for physical prototypes. Their importance relative to other factors in the study is underscored by the fact that their scores rank above the 1.3 average score. This compares to all other design tools which rank below the average 1.3 score, indicating that other factors in the study have a greater impact on product design success.

As we move away from physical prototyping toward virtual design and prototyping, we see a decrease in tools that support physical prototyping and an increase in those that support virtual design. Hence, rapid prototyping technologies will be less important, whereas simulation technologies (product, manufacturing, and assembly) will become more important.

The next most important technologies are empirical ones: designed experiments and competitive benchmarking. They are tools that work in both the physical and the virtual environment. DOE tools are often used to validate simulation and augment the simulation results in areas of the design that cannot be simulated. These tools will gain in importance as experiments become easier to conduct in simulation, and competitive benchmarking results are more rapidly analyzed, disseminated, and integrated into the overall product plan.

The panel was in agreement that drawings and sketches, AI, and VR technologies have little or no influence now and are not expected to in the future. The results on clay models need a little elaboration. While the medians and IQR scores indicate a similar trend to manual drawings or VR, closer examination of the data revealed significant differences between the OEM responses and the supplier responses (see Suppliers, who typically do not use clay models, rate their utility near zero now and in the future. Whereas the OEMs, who use clay models extensively, continue to appreciate their utility and expect their utility to decrease only moderately in the future─as evidenced by the lower IQR values. The use of clay models is not expected to decrease significantly, especially considering the workforce that is active today and expected to be active in the next decade is accustomed to using clay models for decision making.
Table 11).

Suppliers, who typically do not use clay models, rate their utility near zero now and in the future. Whereas the OEMs, who use clay models extensively, continue to appreciate their utility and expect their utility to decrease only moderately in the future─as evidenced by the lower IQR values. The use of clay models is not expected to decrease significantly, especially considering the workforce that is active today and expected to be active in the next decade is accustomed to using clay models for decision making.

Table 11. Median and Quartile Scores for the Design Tool Clay Models by Panelist Organization.

Panelist Organization	Median		Quartile (25/75)	
	2004	2009	2004	2009
Supplier	0.0	0.0	0.0/1.3	0.0/0.0
OEM	10.0	10.0	7.5/15	7.0/10.0

The overall IQR scores (which are among the lowest in the study) show that the panel was generally united in their opinion of the influence of the design tools. However, the overall median values for design tools were not very high, with only 3 scoring above the average 1.3 now and only 2 doing so in the future.

V.3. Influence of Design Criteria

For the following question, please choose the system or systems you are most familiar with. Please identify the system by name in the column heading below. For more than two systems, please include additional pages.

Body	HVAC
Chassis / Suspension	Electrical / Electronics
Engine / Transmission	Test / Validation / Certification
Interior	Other (specify)

Please prioritize the current and future influence of each of the following Design Criteria on your company's product design and development success by distributing 100 points in each column.

The influence of Design Criteria was separated into vehicle systems based on the panelists' expertise. Panelists could respond to any system with which they were familiar. Any system that had more than 5 responses was analyzed separately. Due to a relatively low response rate in both the body and the chassis area, the responses from both were combined and analyzed together. For simplicity sake, the analysis will simply refer to the "body." Hence, the main categories presented below are the Engine/Transmission, Interior, and Body.

V.3.a. Engine / Transmission

Table 12. Median and Quartile Scores for Engine/Transmission Design Criteria

Design Criteria	Median		Quartile (25/75)	
	2004	2009	2004	2009
Final product cost	3.4	2.5	2.3/3.9	1.8/3.6
Product specific performance characteristics	3.2	2.6	2.2/4.0	1.9/3.7
Product quality, reliability, and durability	2.0	1.7	1.7/2.9	1.1/2.2
Product mass	1.6	1.7	1.3/2.7	0.9/2.3
Available product development time / budget	1.6	1.5	1.3/3.2	1.4/2.1
Standardized designs of parts & subsystems; library of design concepts, design templates	1.2	1.5	0.8/2.3	0.9/2.3
Product safety / liability	1.1	0.0	0.0/2.4	0.0/0.6
Packaging constraints	1.0	1.0	0.8/1.9	0.8/1.8
Government regulations	0.8	0.4	0.0/2.1	0.0/2.1
Ease of manufacture and assembly	0.3	0.2	0.0/1.1	0.0/0.7
Ease of service/cost of repair	0.0	0.0	0.0/1.1	0.0/0.8
Recyclability	0.0	0.0	0.0/0.0	0.0/0.3
Aesthetics / styling	0.0	0.0	0.0/0.0	0.0/0.0

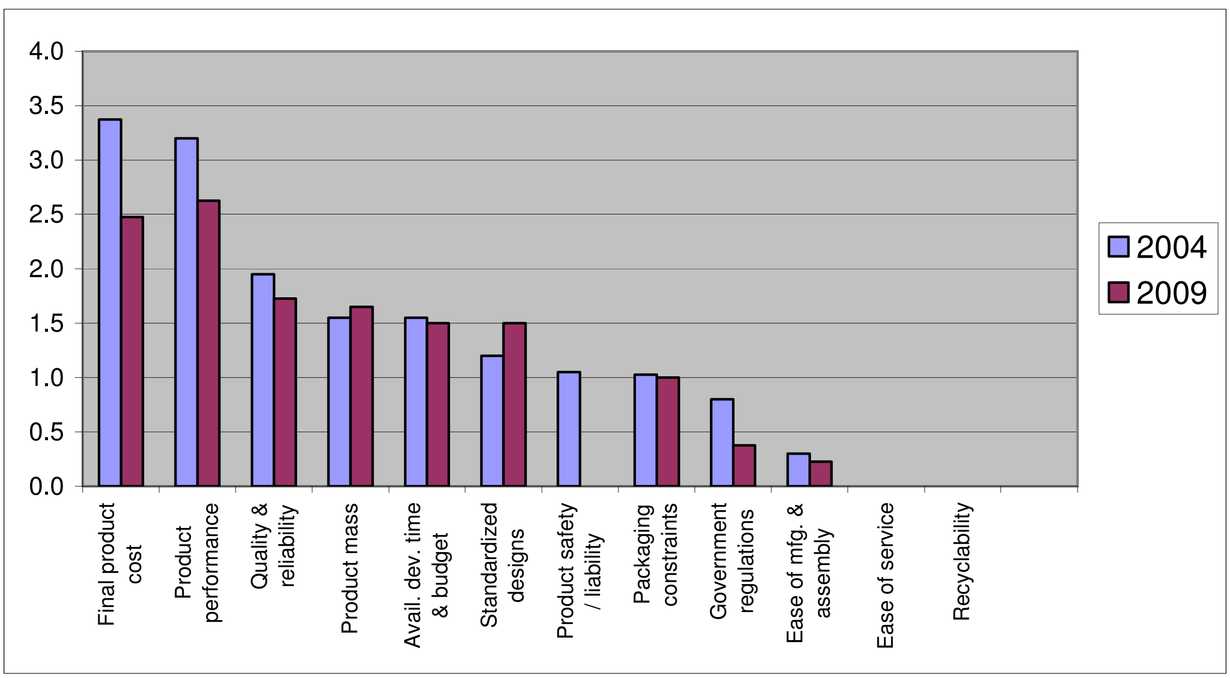


Figure 18. Median Trends for Engine/Transmission Design Criteria.

Discussion and Strategic Considerations:

For powertrain, the design criteria that have the greatest influence on product development success are the product specific performance and final product cost. Product quality and durability is a distant third. Relative to the other factors in the study, these factors are profoundly influential on product development success. Product cost and performance not only ranked above the average weighted factor score of 1.3, but also above the 2.0 limit indicating they are among the most important factors in the study. They are in fact the second and third most important factors.

Further, many of the design criteria are profoundly important as evidenced by their relatively high scores. Product cost, performance, mass, quality and reliability, and PD time and budget all scored above the average 1.3, both now and in the future. Standardized designs will also become a more important design criterion in the future.

The trends are also noteworthy. The two greatest criteria will be less important in the future. Standardization will be a growing criteria, as will product mass. The remaining criteria will either have approximately the same importance or will become less important in the future. The greatest drop is in product safety and liability, which drops to 0 in 5 years. This is presumably due to the increased analysis power, manufacturing capability, and the design standardization and libraries that are making powertrains more of a commodity. This trend is likely to continue as standardization of powertrain designs becomes an increasingly important design criterion.

Other non-existent design criteria are ease of service/repair and recyclability.

The panel differed significantly in the area of government regulations, especially in the Phase II period of the study. While the data shows government regulations decreasing in importance in the future, the OEMs disagreed with the conclusion. CAFÉ, emission regulations, future low sulfur diesel regulations, and other state and federal government regulations are expected to continue to have a strong influence in the future designs of engines.

Clearly, providing a performance powertrain at the lowest cost is a challenge that will always remain. However, despite the uncertainty associated with the revolution that is occurring in powertrains today through advanced diesel and hybrids, the future appears to be relatively bright. The criteria of performance and cost, while still the most important, will be significantly less so in the future.

V.3.b. Interior

Table 13. Median and Quartile Scores for Interior Design Criteria.

Design Criteria	Median		Quartile (25/75)	
	2004	2009	2004	2009
Final product cost	2.8	2.0	2.1/3.0	1.8/2.7
Aesthetics / styling	1.4	1.7	1.2/1.6	0.9/2.5
Available product development time / budget	1.4	1.4	1.2/6.0	0.8/1.9
Product safety / liability	1.3	1.2	1.1/1.5	0.8/1.4
Product quality, reliability, and durability	0.8	0.9	0.8/1.8	0.8/0.9
Standardized designs of parts & subsystems; library of design concepts, design templates	0.8	1.5	0.7/4.2	0.8/3.9
Product mass	0.8	0.9	0.7/2.1	0.8/2.0
Government regulations	0.8	0.8	0.0/0.8	0.0/1.0
Packaging constraints	0.8	0.5	0.6/1.1	0.0/1.0
Ease of manufacture and assembly	0.7	0.8	0.6/0.8	0.5/0.9
Recyclability	0.7	0.8	0.0/0.8	0.5/0.8
Ease of service/cost of repair	0.7	0.4	0.0/0.8	0.0/0.9
Product specific performance characteristics	0.6	0.5	0.0/1.1	0.0/1.4

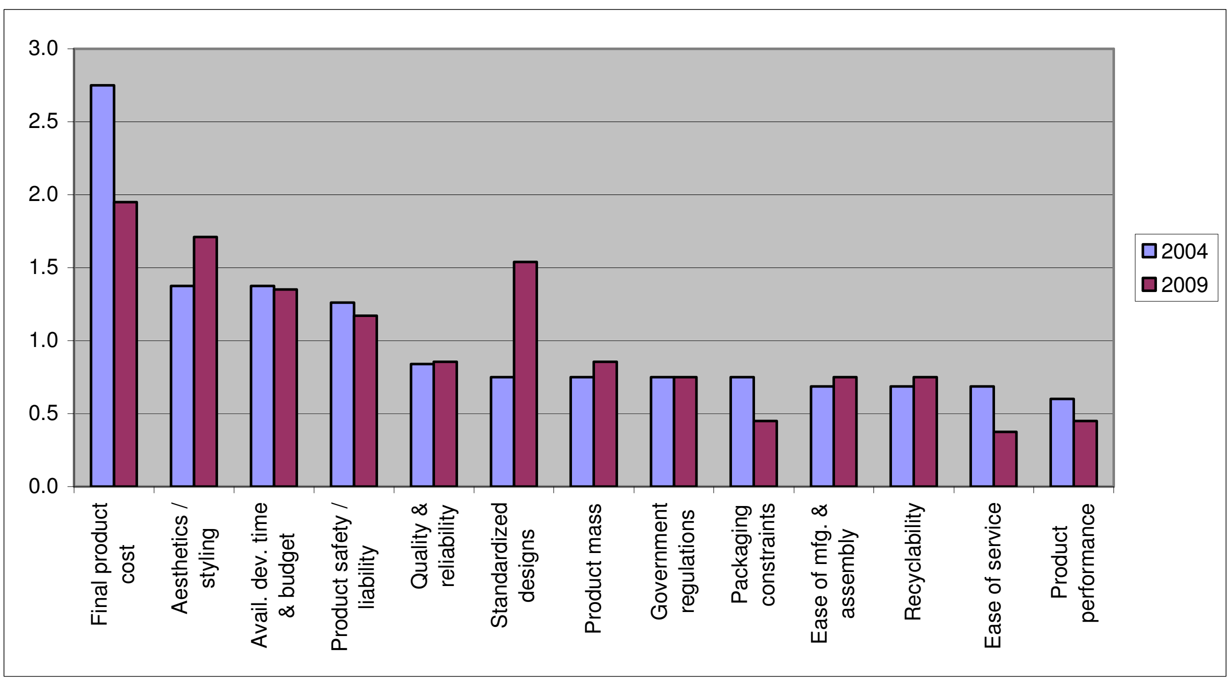


Figure 19. Median Trends of Interior Design Criteria.

Discussion and Strategic Considerations:
As with powertrains, final product cost will be less of a design criterion in the future, and (as can be seen from the IQR), respondents were pretty consistent in their view. Conversely, aesthetics/styling and standardization will become a much more important design criterion—although the panelists were less unanimous in their view.

Along with product development time and budget and safety, these factors scored at or above the average factor score of 1.3, indicating that design criteria are very important factors for interiors (as for powertrain). Also, similar to powertrain, final product cost rose above the 2.0 level—indicating it is one of the most important factors for design success. Unlike powertrain, however, it is not as important a factor in the future and drops to below 2.0. In addition, product performance does not play as prominent a role as in powertrain.

The development and use of standardized interior designs is expected to gain significantly in prominence..

It is believed that these results reflect the trend of commoditization of interiors. Some OEMs have outsourced complete (or significant portions of) interior systems for certain vehicles. Suppliers are finding ways to standardize the bulk of the design with regard to product performance (which will be less of a criterion in the future) while still being able to create outwardly aesthetically pleasing and differentiated products (increasing design criteria). These two factors have a profound impact on cost which will presumably drop and hence be less of a factor in the future.

V.3.c. Body

Table 14. Median and Quartile Scores for Body Design Criteria.

Design Criteria	Median		Quartile (25/75)	
	2004	2009	2004	2009
Final product cost	2.1	2.0	0.8/2.8	1.0/2.7
Product specific performance characteristics	1.5	1.4	1.1/1.8	1.4/1.5
Available product development time / budget	1.4	1.5	1.3/1.5	0.7/1.9
Aesthetics / styling	1.3	1.7	0.0/1.4	0.0/1.7
Ease of manufacture and assembly	1.2	1.5	1.1/1.5	0.9/1.7
Product safety / liability	1.1	1.2	1.0/1.3	1.2/1.4
Product quality, reliability, and durability	0.9	0.9	0.8/1.0	0.9/1.2
Government regulations	0.8	1.0	0.8/1.5	1.0/1.5
Product mass	0.7	0.9	0.5/2.1	0.6/2.0
Standardized designs of parts & subsystems; library of design concepts, design templates	0.7	0.6	0.3/1.3	0.5/1.5
Packaging constraints	0.5	0.6	0.4/1.1	0.2/1.0
Ease of service/cost of repair	0.4	0.7	0.4/0.7	0.2/0.9
Recyclability	0.4	0.2	0.1/0.7	0.2/0.8

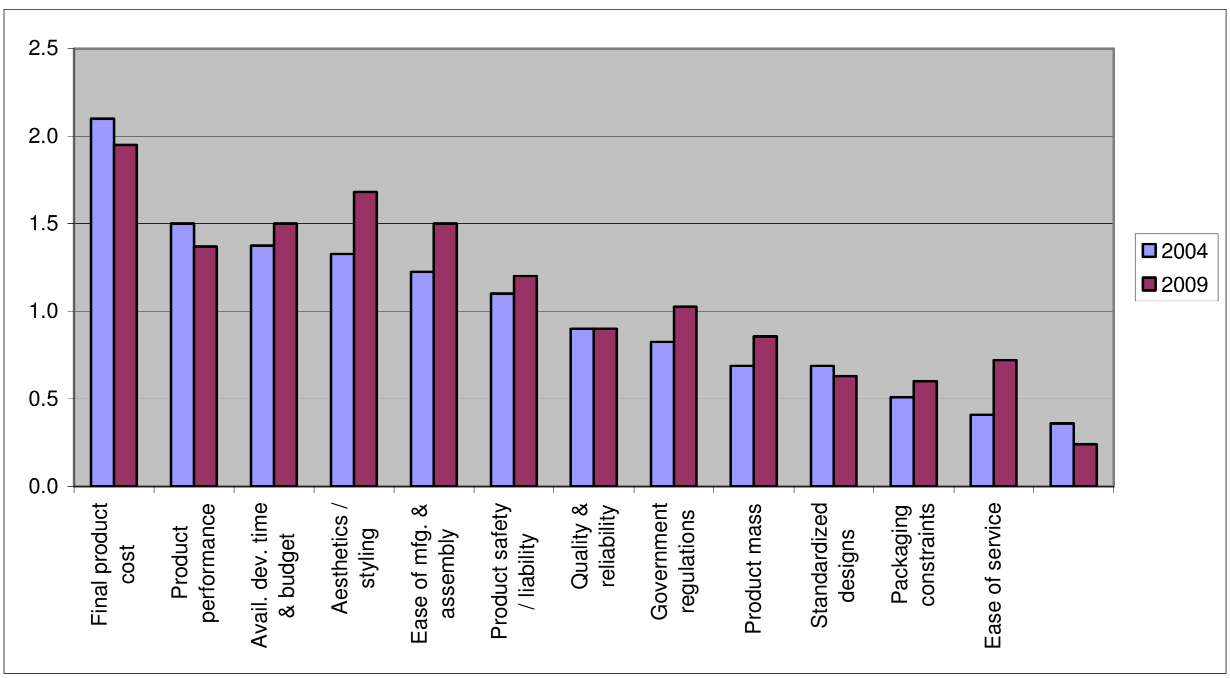


Figure 20. Median Trends for Body Design Criteria.

Select Edited Comments:

- We will always be faced with deadlines and budget.

- I believe that the general industrial concerns relative to safety and the application of electronics to the chassis have a significant impact that can not be overlooked.

Discussion and Strategic Considerations:
As in the other two areas, product cost is and will remain the most important design criteria. Its relative importance is also expected to decrease in the future, but not below any other criteria. Its score is above the average 1.3 both now and in the future, and its current score is above 2.0, indicating it is one of the most important factors on product development success in the study.

Product performance is currently the second most important criteria, and similar to the other vehicle areas, its relative importance is expected to decrease in the future. But it still remains an important factor, scoring both now and in the future above the average 1.3 score.

Again, as in other areas, there are several other design criteria that have an above average score: styling, product development time and budget, and ease of manufacture. This fact again points to the importance of design criteria relative to other factors, even though the specific criteria may change depending on the vehicle system. Of the criteria that are expected to increase in importance, styling, ease of manufacture, and PD time and budget move from third through fifth place to second through fourth, eclipsing product performance.

Unlike in interiors or powertrain, the remaining criteria are expected to increase or retain the same level of importance. Panelists believe bodies will have an increasing influence on design in the future and that all criteria will have to be met, implying that it will become more difficult to design vehicle bodies.

It is interesting to note that, with the exception of the most important criteria—product cost—the IQR values of all the criteria for body are lower than the IQR values for the other vehicle areas. This means the panelists were in closer agreement with one another as to the relative importance of the criteria in the body than in the other two areas of the vehicle.

Increased use of carry-over parts, increased flexibility within an architecture/platform to create multiple models, and increased manufacturing flexibility are major trends in body design. These major trends are expected to enable vehicle manufacturers to design and manufacture a wide variety of aesthetically pleasing body styles—for relatively low cost in a relatively short amount of time. We see these trends reflected in the respondent's view of design criteria, namely increasing standardization, increasing ease of manufacture/assembly, increase in styling, and an increase in the time and cost it takes for development, while product cost and performance decrease in importance.

The body is the vehicle system that is most visible to the customer and hence important to change relatively frequently. This makes styling increasingly important.

Of course, other criteria, such as weight, government crash regulations and CAFÉ rules, will only gain in importance in the future, as more and more demands are placed on the body. The panelists comments on electronics and the chassis are only one example emphasizing the importance of reliability and safety as the complexity of the system interactions grows.

VI. Interactions and Collaboration

These questions address issues concerning communication and collaboration, between functions and between organizations. Thus, there were two primary questions: how much more do certain functions need to communicate, and what methods of communication have the greatest impact within the organization or between the organization and its customers or suppliers?

Again, the analysis is based on the weighted responses. Every response here can be compared on the same scale with every other response in the weighted analysis section. This means that while the instructions asked the panelist to distribute 100 points across the question, the response was multiplied by the relative weights for the question. Thus, the reported median scores will not sum to 100 within the questions.

Two benchmarks are the following. First, the average weighted score is approximately 1.3. Thus, any score that ranks above a 1.3 is an above average weight. Second, those factors scoring a 2 or higher rose to prominence above all other factors (see Section III.3. Overall Weighted Factor Comparison).

VI.1. Communication Methods

Collaboration has been shown to be a large issue in product development. And effective collaboration requires effective communication. However, the communication method and the effectiveness of communication can vary within the organization, between the organization and its suppliers, and between the organization and its customers. To capture this difference, we asked the panelists to respond to the same question three times depending on the particular situation.

The instructions were:

Please prioritize the current and future effectiveness of each of the following Communication Methods in communicating within your organization, with your suppliers, and with your customers (only suppliers should complete this column) on your product development success by distributing 100 points in each column.

Each response is discussed in the following pages.

VI.1.a. Communication within an Organization

Table 15. Median and Quartile Scores for Communication Methods within the Organization.

Communication Method	Median		Quartile (25/75)	
	2004	2009	2004	2009
Electronic communication (i.e., internet / email / ftp)	4.2	4.5	3.4/4.5	3.6/6.0
Physical face-to-face meetings	3.0	2.0	1.9/4.8	1.4/3.5
Co-location within a common work area	1.8	1.7	0.9/2.3	1.6/2.8
Print-based communication (memos, letters, reports, Overnight mail etc.)	1.5	0.7	0.9/2.0	0.2/1.3
Interactive computer tools and use of common databases	1.2	1.4	0.4/2.1	0.7/2.9
Voice mail and fax	1.1	1.2	0.9/2.3	0.9/2.4
Video conferencing	0.7	1.0	0.3/1.1	0.8/1.4
Web-based collaboration tools	0.3	1.5	0.0/1.1	0.4/1.9
Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.7	0.0/0.8

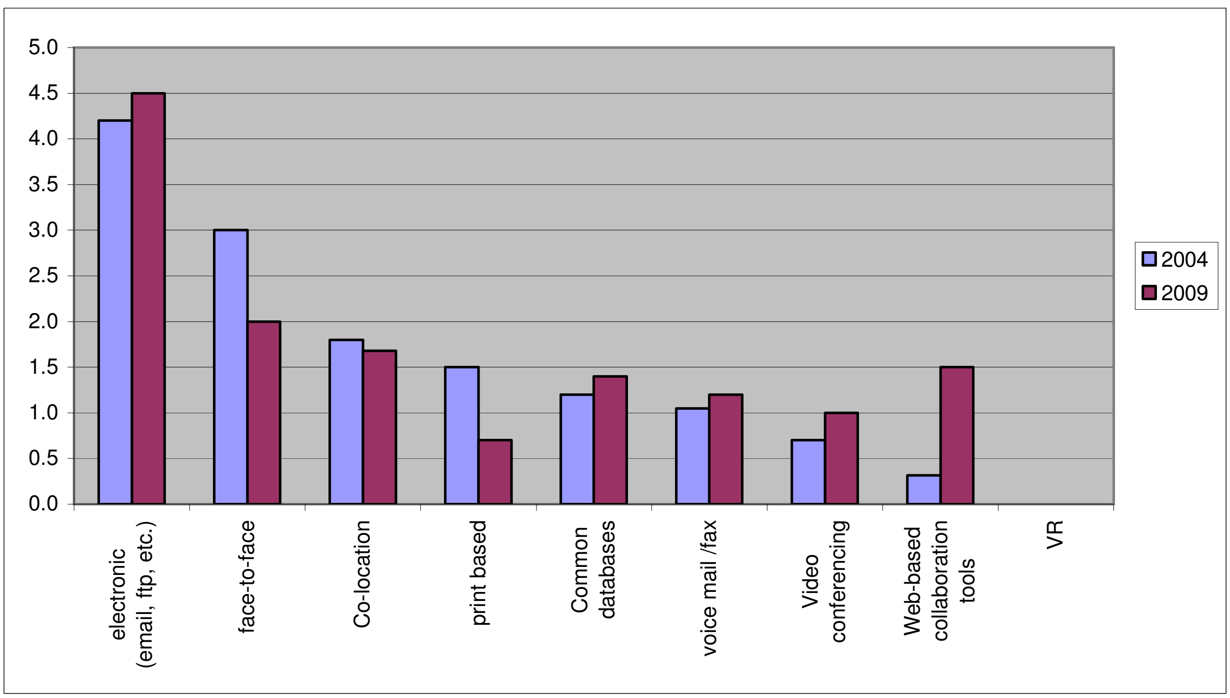


Figure 21. Median Trends of Communication Methods within the Organization

Select Edited Comments:

- Electronic communication is increasing, but will include more interactive tools.

Discussion and Strategic Considerations:
Clearly, electronic communication is considered the most effective communication tool for product design within an organization. Its importance is only expected to grow; however, some believe this will have a greater impact than others, as evidenced by an increase in the 2009 IQR.

The second most effective means of communication within an organization is face-to-face meetings, although there is unanimous agreement that its effectiveness is expected to drop. Despite its drop, however, it retains its second place ranking to other communication methods.

Both electronic and face-to face communication are among the most important factors in the study, both ranking above the 2.0 mark (see Section III.3.a. Communication within the Organization). Electronic communication is the most important factor in the study, and face-to-face communication remains above the 2.0 mark despite its marked anticipated future decline. In fact, communication methods in general are believed to be more important than many other factors in the study: six of the nine communication methods score above the 1.3 average factor score either now or in the future.

Collocation of relevant personnel is third and is expected to remain roughly in the same position. Closer examination of the IQR values is interesting. Both the 25^{th} and 75^{th} percentiles increase in value, while the 50^{th} percentile (median) decreased slightly in value. Thus, the lower half of the distribution believes collocation will be more important in the future, as do a few of the upper half. While the overall 50% point does not move, the panel generally believes collocation will become a more effective means of communication in the future.

The other two communication methods of note are print-based communication (expected to drop sharply as an effective communication method) and web-based collaboration (expected to grow sharply, overtaking video conferencing). The panel was in unanimous agreement over the relative effectiveness of both of these communication methods.

Clearly, technology has changed the way people communicate. The panel expects this trend to continue in the future─especially as web based collaboration tools develop and gain acceptance in the industry, as echoed in one of the panelist's comments. These communication tools speed the transfer of objective information required for coordinated decision making on a variety of issues. However, it cannot completely replace face-to-face meetings. Physical meetings are superior when one must repeatedly exchange a large amount of complex and subjective information. In team building, strategic planning, negotiations, conflict resolution, and other similar situations, it is necessary to build a sense of trust and understanding with others in the meeting─most effectively achieved face-to-face.

VI.1.b. Communication between an Organization and its Suppliers

Table 16. Median and Quartile Scores of Communication Methods with Suppliers.

Communication Method	Median		Quartile (25/75)	
	2004	2009	2004	2009
Electronic communication (i.e., internet / email / ftp)	4.2	3.8	2.8/6.3	3.1/7.2
Voice mail and fax	2.5	2.0	1.3/2.9	1.3/3.1
Physical face-to-face meetings	2.3	2.1	2.1/3.6	1.5/2.8
Print-based communication (memos, letters, reports, Overnight mail etc.)	2.1	1.5	0.7/3.4	0.5/2.0
Interactive computer tools and use of common databases	1.3	1.1	0.5/1.5	0.2/2.8
Web-based collaboration tools	0.8	1.5	0.0/1.4	0.8/1.8
Video conferencing	0.5	0.9	0.0/0.7	0.2/1.5
Co-location within a common work area	0.0	0.9	0.0/0.6	0.0/1.6
Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.6	0.0/1.4

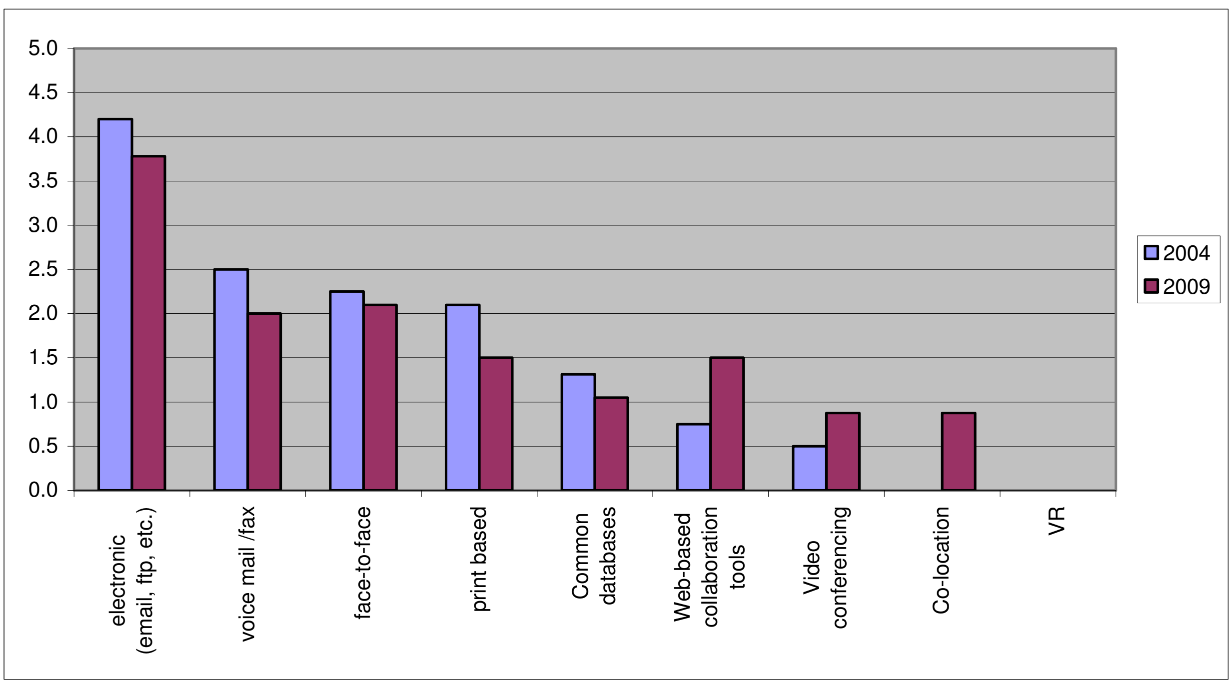


Figure 22. Median Trends for Communication Methods with Suppliers.

Select Edited Comments:

- Electronic communication is increasing, but will include more interactive tools.

Discussion and Strategic Considerations:
The general conclusions drawn from the Within Organization analysis are true here also. Communication methods are important relative to other factors with 6 of the 9 communication methods scoring above the average 1.3 factor score in 2004 or 2009.

Further electronic communication is the most effective means of communication, scoring well above the 2.0 mark making it the most important factor relative to all other factors in the study (see Section III.3.b. Communication with Suppliers). However, its effectiveness is believed to decrease in the future. This is in marked contrast to the Within Organization response. Also, the IQR is high, meaning that there was no consensus among the panelists. It is interesting to note that both the top and bottom 25th percentile of the panelists believe that the importance of electronic communication will increase in the next 5 years. This might indicate that the slight drop in the median value is not significant.

Voice mail and face-to-face meetings are second and third, both showing a small decline. The IQR percentiles from face-to-face show that the decline may be actually stronger than it appears from the median scores. Both percentiles indicate that the top and bottom 25 percent of panelists who felt it is an effective means of communication now, strongly believed it would not be so in 2009.

Again, print is strongly declining as an effective means of communication, while web-based collaboration tools and video conferencing is increasing, as is collocation, facilitating face-to-face communication. Virtual environments are not something anyone expects to use to communicate with suppliers in the near future.

Clearly technology has changed the way people communicate. The panel expects this trend to continue in the future, especially as web based collaboration tools develop and gain acceptance in the industry—echoed in one of the panelist's comments. These communication tools speed the transfer of objective information required for coordinated decision making on a variety of issues. However, they cannot completely replace face-to-face meetings. Physical meetings are superior when one must repeatedly exchange a large amount of complex and subjective information. Team building, strategic planning, negotiations, conflict resolution, and other similar situations, are necessary to build a sense of trust and understanding with others in the meeting—most effectively achieved face-to-face.

VI.1.c. Communication between an Organization and its Customers (Suppliers only).

Table 17. Median and Quartile Scores for Communication Methods with Customers.

Communication Method	Median		Quartile (25/75)	
	2004	2009	2004	2009
Electronic communication (i.e., internet / email / ftp)	4.2	4.4	3.8/6.0	3.2/8.0
Physical face-to-face meetings	2.8	2.0	2.1/3.2	1.4/3.2
Print-based communication (memos, letters, reports, Overnight mail etc.)	2.6	0.8	0.8/3.6	0.3/1.8
Voice mail and fax	1.5	1.6	1.3/3.5	0.8/2.6
Interactive computer tools and use of common databases	1.2	1.4	0.3/1.5	0.4/3.0
Web-based collaboration tools	0.8	1.6	0.0/1.3	0.8/2.3
Co-location within a common work area	0.5	1.5	0.2/1.2	0.0/1.6
Video conferencing	0.5	0.8	0.0/0.8	0.4/1.0
Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.5	0.0/1.1

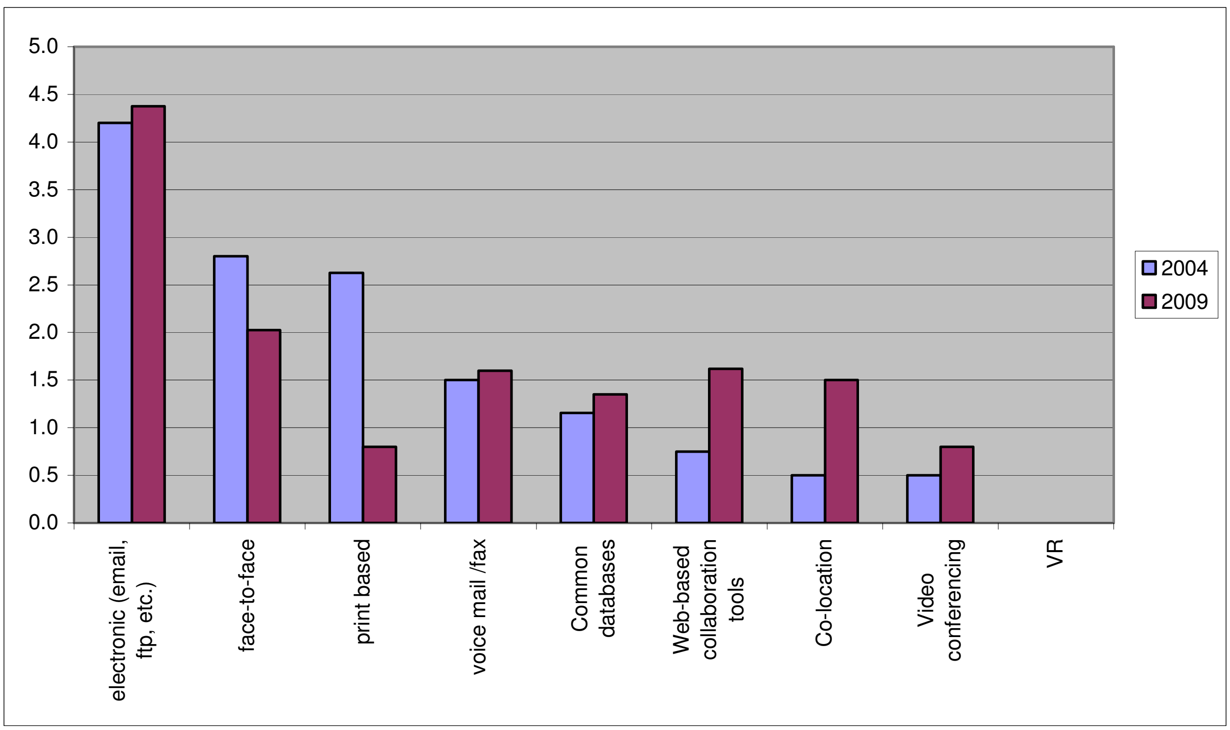


Figure 23. Median Trends for Communication Methods with Customers.

Select Edited Comments:

- Electronic communication is increasing, but will include more interactive tools.

Discussion and Strategic Considerations:
The general conclusions drawn from the previous two sections are true here also. Communication methods are even more important with the customer, relative to other factors, with 7 of the 9 communication methods scoring above the average 1.3 factor score in 2004 or 2009.

Further electronic communication is again the most effective means of communication, scoring well above the 2.0 mark, making it the most important factor relative to all other factors in the study (see Section III.3.c. Communication with Customers). Print media sees again a marked decline. And face-to-face interaction declines as web-based collaboration, collocation, and video conferencing increases. But, the panel is divided on a number of these communication methods.

The IQR increases for electronic communication, use of a common database, web-based collaboration tools, collocation, and face-to-face communication. This indicates that the panel does not really have a consensus for how suppliers will be communicating in the future with their customers.

The panel sees a shift in the communication methods coming in the future. Face-to-face communication between an organization and its suppliers is more important than within an organization, because face-to-face meetings are more effective in establishing a sense of trust which is necessary when dealing with complex issues. This is particularly important when there can be a difference in corporate values, dealing with contractual matters, and establishing long term relationships─vitally important in a supplier relationship.

Email is replacing print media. With the improved speed of the internet, software capable of reading a variety of formats, increased computing power and storage technology, and the declining cost of technology, it is now possible to send product data to anyone anywhere in real time. This dramatically speeds up decision making; speed will continue to be the main driver in the foreseeable future.

Video conferencing and web-based collaboration is replacing face-to-face communication. This is useful for the high information content exchange of structured information or where there is a reasonably structured/objective decision making process where trust is not as much of an issue.

Face-to-face appears to be important as collocation across all organizations is expected to increase. While electronic means of communication work well for engineering and other structured forms of information, face-to-face meetings are still considered necessary when it comes to decision making, particularly across functional boundaries. Since this typically involves negotiation and trust, face-to-face through collocation is considered to be an effective means of communication.

One might expect face-to-face communication to increase in effectiveness. However, we believe this trend is not occurring for two reasons. One is the increase in web-based collaboration tools and video conferencing mentioned above. Another is the change in business processes. OEMs are focusing on working with a select range of suppliers to build this trust. Hence, as OEMs reduce their supplier base, there will not be as much communication overhead. Also, procedures are being established and the design process is becoming more efficient, increasing structured and objective decision making and requiring fewer face-to-face meetings.

This drive toward electronic communication appears to be driven from the customer down through the supply chain. Print media and face-to-face interaction falls much more rapidly with customers than with suppliers.

Clearly, technology has changed the way people communicate, and the panel expects this trend to continue in the future, especially as web based collaboration tools develop and gain acceptance in the industry. These communication tools speed the transfer of objective information required for coordinated decision making on a variety of issues. However, it cannot completely replace face-to-face meetings. Physical meetings are superior when one must repeatedly exchange a large amount of complex and subjective information. Typical situations regarding such information exchange involve team building, strategic planning, negotiations and conflict resolution. In these and similar situations, it is necessary to build a sense of trust and understanding with the others in the meeting, which is most effectively achieved face-to-face.

VI.2.Impact of Organizational and Human Resource Management Factors

Please prioritize the current and future impact of each of the following Organizational and Human Resource Management Factors on your company's product design and development success by distributing 100 points in each column.

Table 18. Median and Quartile Scores for Organizational and Human Resource Management Factors.

Human Resource Management Factors	**Median**		**Quartile (25/75)**	
	2004	**2009**	**2004**	**2009**
All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1

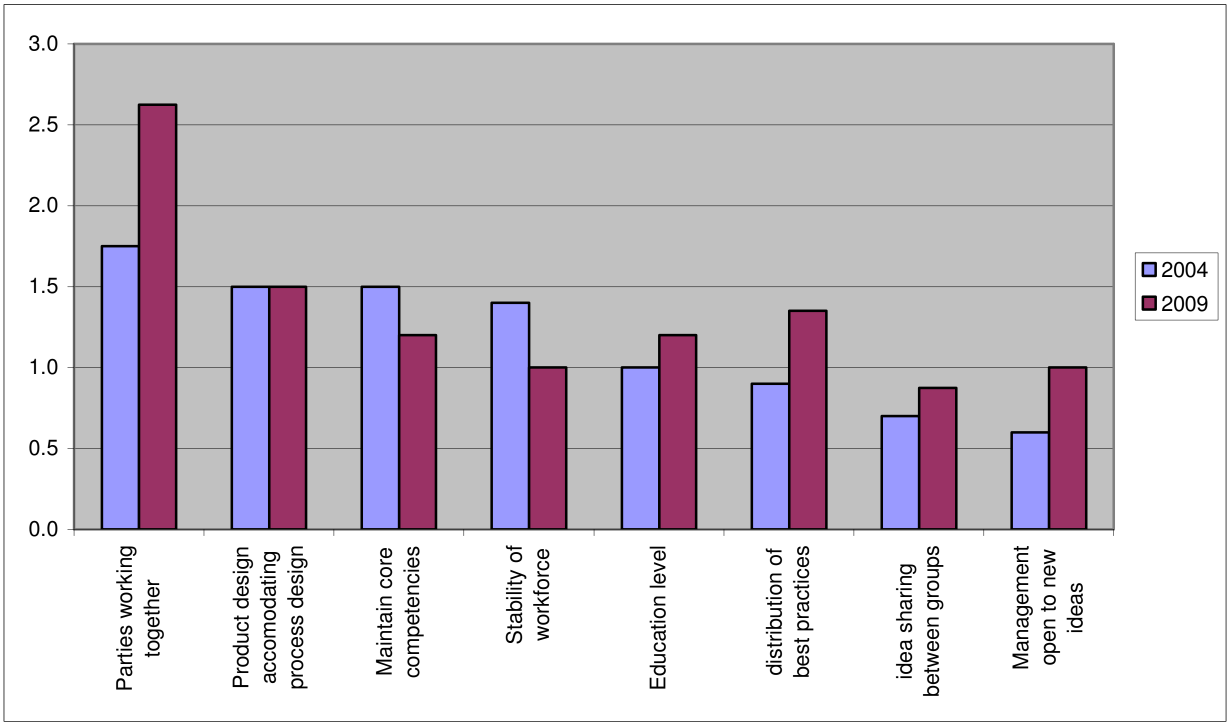


Figure 24. Median Trends for Organizational and Human Resource Management Factors.

Select Edited Comments:

- There is a shift to more common goals and trusting functions to be responsible.

Discussion and Strategic Considerations:

Examination of the scores indicates that here too many factors are above average (score > 1.3) relative to the other factors in the study: parties working together, product design accommodating process design, maintaining core competencies, workforce stability (currently), and in the future the distribution of best practices. With 5 of 8 factors scoring above the average, organizational and human resource management factors are very important to successful product design.

The panelists were in general agreement that all parties effectively working together towards a common goal is the HRM factor that has the greatest impact on product design. The majority of the panel also believed that this impact would increase in the future by over 40%. Accommodating process design is the second most important factor and will remain so in the future. The remaining factors appear to converge in importance; maintaining core competency and workforce stability decline in importance as education level, distribution of best practices, idea sharing, and having a management that is open to new ideas all gain in importance. In general, the panel agreed on all issues as evidenced by the stable IQR scores.

Successful product design is clearly a team effort that requires the input of various groups all working toward a common goal. Hence, it is understandable that this factor ranks the highest. It is also understandable that accommodating process design ranks second, as every successful design must be manufacturable. The remaining factors point to a reliance on improving the product design process and an increase in innovation and ideas.

An effective disciplined product design process that is adhered to can compensate, to some degree, for a mobile and changing workforce.   Similarly, as processes are implemented to maintain core competencies, the organization can focus on other issues trusting their process will achieve its goal. This means that the importance of maintaining core competencies relative to other factors will decrease.

The future focus of the organization then becomes how to create an innovative workforce where ideas flourish and are distributed within the organization. Hence, we see an increase in the importance of having a more educated workforce, a management that is open to new ideas and idea sharing between product teams, and the distribution of best practices.

VII. General Questions

The previous questions were weighted questions, because we were interested in the relative impact various factors have on product development and how that is expected to change in the future. However, there are other issues related to product development that are also of interest: engineering efficiency, product development time, and barriers to product development. The results of these questions are presented and discussed in this section.

VII.1. Engineering Efficiency

Engineering efficiency is a new topic that was not part of previous Delphi studies. The various mechanisms and areas that organizations are focusing upon to achieve greater engineering efficiency as well as the metrics of engineering efficiency are of particular interest.

VII.1.a. Improvements

Please prioritize which areas your company is currently focused upon (expending resources to implement) and will be focusing upon in the future to improve engineering efficiency by distributing 100 points to each column. If improvements in other areas of the organization are also anticipated that thereby influence your response, please explain in the comments section.

Table 19. Median and Quartile Scores for Engineering Efficiency Improvements.

Engineering Efficiency Improvements	**Median**		**Quartile (25/75)**	
	2004	**2009**	**2004**	**2009**
Increase MBE	15	18	10/20	10/21
Increase process discipline	13	12	10/20	10/20
Increase collaboration/communication	12	10	10/15	7/15
CAD/CAE/FEA/CFD	10	10	10/15	9/10
Investment in PDM	10	10	5/15	9/15
Hardware improvements	5	10	5/13	9/12
Increase product/process training	5	10	5/10	7/0
Increase other training	5	8	5/8	5/10
Improvement in HR management	5	6	5/6	5/8

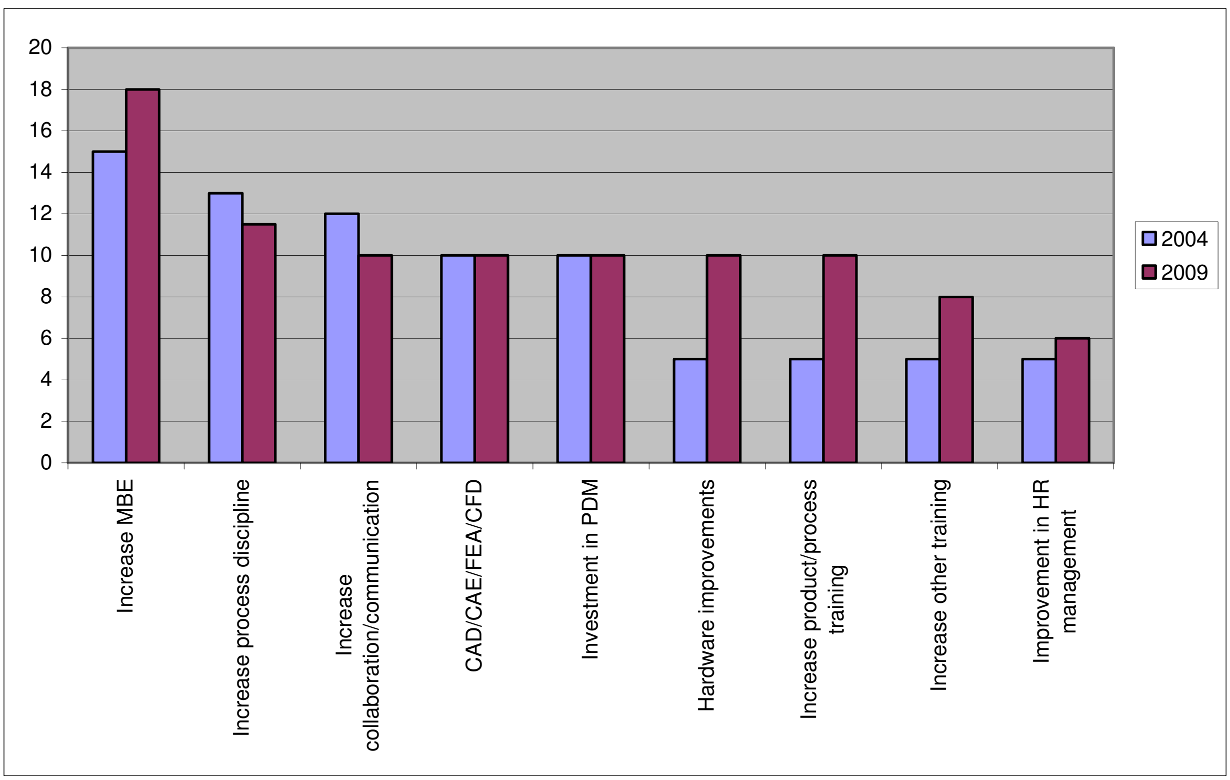


Figure 25. Median Trends in Engineering Efficiency Improvements.

Selected Edited Comments:

- Web-X based conferencing has been a key enabler.

Discussion and Strategic Considerations:
Math-based engineering is by far the greatest focus area for improving engineering efficiency and will become even more so in the future. Increasing process discipline is the second most important focus area and will remain so in the future despite a slight decline in its relative importance. Increasing collaboration and communication is currently third, with improvements in hardware and more established software (such as CAD/FEA and PDM system) tied for fourth. In the future, these will be tied for third, with product and process training. In the future, the panel expects organizations to focus more on training in all areas.

Examination of the quartiles indicates that increasing MBE and design discipline have the greatest IQR. This is because the panel was split as to which of the two was most important. Most organizations are focusing on increasing MBE with some focusing on increasing process discipline. Of those that are focusing on MBE, they also generally focus on CAD/CAE/FEA/CFD.

The responses reinforce the main themes seen in the weighted questions. Clearly, math-based engineering methods, i.e., simulation tools, not only reduce costs by reducing the number of physical prototypes required (see section 0. Some changes to the current survey include the questions on global design and global manufacturing. While it was anticipated that these methods would rank higher, their low score might be explained as follows. Although global sourcing and manufacturing of products that are accepted globally continue to be a priority, many OEMs have handled this challenge in ways that have a relatively low impact on product design effectiveness. Some have a standardized global production system. Hence, their particular product design could practically be manufactured anywhere. Also, the move toward manufacturing flexibility has given designers relatively more freedom to design products that can be produced globally. Lastly, it is possible that since most products are designed with a manufacturing plant in mind, designers may be taking those issues into account. Others have purchased companies or created alliances with companies that enable platform sharing to deal with regional differences.
Impact of Design Tools), but also reduce the amount of time required to conduct analyses, and improve the quality of design decisions by enabling various design alternatives to be explored quickly. All of these advantages result in improved engineering efficiency.

The overall communication theme seen in previous questions is also in evidence here, as one panelist commented. Improving collaboration and the speed of information flow both contribute to improved decisions. Further, cross functional collaboration and communication ensure that other functional areas within and between organizations are involved and aware of the decisions being made, resulting in faster execution. Engineering efficiency is directly related to the speed and quality of engineering design decisions.

It is also interesting to note the future focus on training and personnel development. This is presumably a partial response to the exodus of institutional knowledge expected to occur as the baby boomers retire. But, training does not rise to overtake the other factors of math-based engineering, increased process discipline, and collaboration and communication. This may indicate that with increased engineering efficiency, fewer engineers are needed to design successful products.

VII.1.b. Metrics

What metrics / measures does your organization use to evaluate engineering efficiency and effectiveness? Please comment below.

Discussion and Strategic Considerations
It is interesting to see how different organizations use various metrics to quantify engineering efficiency. The metrics were divided into the following categories: Financial, Timeliness and Completeness, Design Quality, Personnel, and Miscellaneous.

All organizations have measures of engineering efficiency. Most are well known; traditional program management metrics focused on individual programs, such as comparing planned to achieved targets or milestones and resource use. Others are more macro-focused evaluating the engineering effort as a whole across all projects, such as gross engineering costs and percent annual productivity change. Finally, there are a few measures that are different and which the reader may find of interest.

Financial:
The financial metrics mentioned by the panelists typically measure the actual cost and compare it to the planned cost in various categories. The major categories are well known and encompass the major expenditures for product design:

- Gross engineering cost ($)
- Customer prototype cost ($)
- Internal prototype cost ($)
- Testing cost ($)
- Overhead cost ($)
- Product Cost ($)
- Program Cost ($)

In some cases the costs are put into perspective with other efforts related to product design, such as innovation and research. Hence, the following was also mentioned:

- % of resources for Sustaining, Innovation and R&D

Timeliness and completeness measures:
Timeliness and completeness measures are similar to cost, in that one measures either the time it takes to achieve a particular milestone, or one measures the percent of projects that achieve the milestone by a certain date. These latter milestones are also often called percent first pass. Typical milestones or gates are:

- Bill of Materials complete and approved
- Theme and surface complete and approved
- Drawing Release
- Customer release
- Prototype delivery
- Engineering release
- Process design verification
- Pre-production release (days)
- Production release (days)

Design Quality:
Design quality measures vary from organization to organization. They typically involve some measure that attempts to quantify how well the design function achieved certain objectives. These objectives can be product specific (such as weight management) or they can be aligned with organizational goals, such as carryover parts usage.

- Carryover parts usage (%)
- Number of variations for similar products (part count)
- Weight Management
- Cost avoidance and cost savings ($)
- Product Improvement (number of improvements)
- Number of engineering changes before and after start of production (categorized by cause, e.g., production issue, safety issue, etc.).

Design Process Efficiency
Design process measures are metrics intended to quantify the efficiency or cost effectiveness of the design process over all engineering design activities. These are generally referred to as productivity or efficiency measures. The ones quoted by the panel are:

- Productivity = (Sales – Materials)/Engineering Labor
- Productivity = Engineering cost / sales (inverse of above)
- Productivity = (number of part numbers going through the PDP process)/(current year engineering expense)
- % Change in productivity = (Productivity for 2004– Productivity for 2003) / (Productivity for 2003)
- Project throughput

Personnel
The personnel measures mentioned by members of the panel are interesting in that they actually measure various aspects which are all relatively different.

- Total headcount
- Offshore usage (%)
- Performance review timeliness (%)
- Utilization of staff per engineering group per customer

For example, total headcount correlates most closely with overall department budget. The percent offshore usage (either as headcount, percent labor, or percent labor dollars) is a measure of how much of the engineering design has been outsourced. Under the assumption that outsourced engineering is more cost efficient, then this is another aspect of the cost metric. Performance review timeliness is another aspect of how well the department is managed. Timely performance reviews are related to timely feedback to the individual engineers on their productivity and performance. This action would affect future engineering quality, engineering motivation, and alignment of individual performance with organizational goals. Staff utilization as a function of the customer is an interesting measure. It combines certain cost metrics with the particular customer. This provides some indication as to which customers require more engineering effort versus other customers.

Miscellaneous
The last two metrics did not readily fit into any of the other categories.

- Number of IP filings and awards
- Annual Customer Satisfaction Survey

The number of IP filings and awards is a measure of innovation, but not necessarily one of design quality, nor of engineering productivity. An annual customer satisfaction survey (mentioned by one panelist), which one would expect to contain some measures of design quality, is also likely to cover much more.

VII.2. Collaboration

A major theme that has emerged from the study is the theme of communication and collaboration. This was not entirely unexpected; we had included a section similar to previous Delphi studies on this topic. However, unlike the previous studies which asked how well various groups worked together, we rephrased the question asking which groups need to work more closely together (assuming that no one should work less closely together). We then followed up with a question on how groups that should work much more closely together might achieve this result (enablers).

We also added two other “functions”. With the increase in outsourcing that has occurred and is expected to continue, the supplier is playing a more dominant role in product design. Further, if one follows the Japanese model, one can argue that the supplier is an extended function of the organization, and hence should be viewed as part of the organization. We added the customer as another function for similar reasons. From a supplier’s perspective, they might consider themselves an extended part of their customer’s organization.

VII.2.a. Interactions between functions

Based on your experience with your company, which functions / stakeholders should work more closely together in order to improve time, cost or quality in the PD&D cycle? Please rate the desired change according to the scale provided, where

Scale:
1 = Interaction is sufficient,
2 = Increased interaction desired,
3 = Should work much more closely together

Table 20. Median Scores for Interactions between Functions.

Function	Styling	Engineering Design	Manufacturing	Purchasing	Supplier	Sales and Marketing	Customer
Styling		2.0	1.4	1.1	1.1	1.3	1.1
Engineering Design	2.0		2.6	2.3	2.2	1.7	1.6
Manufacturing	1.4	2.6		1.8	1.9	1.6	1.6
Purchasing	1.1	2.3	1.8		1.6	1.4	1.5
Supplier	1.1	2.2	1.9	1.6		1.1	1.4
Sales and Marketing	1.3	1.7	1.6	1.4	1.1		1.5
Customer	1.1	1.6	1.6	1.5	1.4	1.5	

Discussion and Strategic Considerations:
The first item of interest is that the panel believes that every organizational function should collaborate more closely with engineering design than with any other function. This is presumably an artifact of the panel consisting of individuals representing engineering design. However, looking closer at the numbers, one does notice that collaboration between product design and manufacturing needs to increase the most. This is consistent with the design for manufacturing responses seen in earlier questions.

Following manufacturing, collaboration between product design and purchasing and the supply chain needs to increase the most. This is not surprising given the trend in outsourcing of the manufacture and design of major subassemblies, a trend that is expected to grow. After that follows styling which is presumably closer in function to product design than sales and marketing are to the customer.

After product design, manufacturing requires the most interaction with the rest of the organization, but in particular with suppliers and purchasing. Again, this is not surprising given the amount of outsourcing.

On the other end of the spectrum, styling's interaction with the various other functions is generally sufficient and does not require a major increase in collaboration.

In general the expectation was that adjacent groups, i.e., styling and product design, product design and manufacturing, manufacturing and purchasing, etc., would have the strongest need to collaborate. It was surprising to see the strength with which collaboration with the customers was mentioned. While the need for collaboration was not perceived to be nearly as strong as in product design, it was also not as weak as in styling. Again, this may be another effect of outsourcing, which not only requires more interaction with the supply chain (if you are the customer), but also more interaction with the customer (if you are the supplier).

VII.2.b. Enablers for increased interactions

Please list the technological or organizational enablers necessary to improve the interaction between the function / stakeholder pairs you rated as "3 – Should work much more closely together" in the previous question. Please add additional pages as necessary.

Example: In question 0. you place a 3 in the Engineering Design / Manufacturing square. Then for this question Engineering Design would be Function/Stakeholder A and Manufacturing would be Function/Stakeholder B. Enablers might be: collocation, require manufacturing to buyoff product design prior to tool release, engineering design to document design and inspection intent by part and provide to manufacturing, etc.

Discussion and Strategic Considerations:
The enablers were examined and grouped according to similar themes. The themes and enablers are given in Table 21 below. Figure 26 shows the percent of total responses given within each theme. Each theme is described below.

Communication
Comments under this category essentially spoke to the need for both groups to better understand each others concerns, or made suggestions targeted at improving communication, such as collocation.

Engineering Tools
Engineering tools refer to enablers that are based on engineering tools, such as manufacturing process simulation, value analysis, translation of customer wants into product features (QFD), and design for six sigma.

Organizational
Organizational enablers are similar to process enablers, but typically require a larger change in the organization than can be achieved through a process change. Examples include reorganization, the creation of dedicated quality and supplier management engineers, obtaining additional resources, and having common manufacturing processes across all production facilities.

Process
Process enablers are similar to organizational enablers, but only require changes to the decision making process. Typically these changes are suggested as a means to motivate and ensure communication between the stakeholders. Typical suggestions are requiring the groups to attend each others review meetings or to review and approve of each others major decisions, e.g., design and process approval.

Miscellaneous
Miscellaneous is everything else that did not fit well into any of the above groups. There was only one comment that fell into miscellaneous: increased plant engineering experience for suppliers and purchasing to enable communication with manufacturing. This is really an educational component that involves both communication and organizational change, and thus

could be categorized in either. Adding the comment to either category would not significantly change the results.

Table 21. Interaction Enablers between Stakeholder A and Stakeholder B and the Corresponding Theme.

Stakeholder A	Stakeholder B	Enabler	Theme
Engineering Design	Styling	Collocation of styling and design	communication
		Find common ground, find value in each others Function, explain decisions	communication
		Design communicate to styling tooling requirements and rational	communication
	Manufacturing	Collocation of design and manufacturing	communication
		Design sign-off of manufacturing decisions	process
		Brainstorming between design and manufacturing	communication
		Additional resources	organizational
		Reorganization	organizational
		Collocation for early development	communication
		Value engineering/value analysis	eng. tools
		Manufacturing process simulation	eng. tools
		Managing engineering changes	process
		Dedicated quality engineers	organizational
		Manufacturing attend design reviews	process
		Common mfg. processes across mfg. plants.	organizational
		Formalize VA/VE process	process
		Manufacturing signoff on design	process
	Purchasing	Engineering approval of suppliers	process
		Supplier review of overall design	process
		Additional resources	organizational
		Reorganization	organizational
		Engineering change process	process
		Early supplier identification	process
		Early supplier involvement	communication
		Engineering accountability for cost reductions	process
		Dedicated supply chain engineers	organizational
	Sales & Marketing	Communicate early program requirements	communication
		Manage customer expectations	process
		Translate of customer wants into product features	eng. tools
	Supplier	Early supplier nomination	process
		Proven supplier process capability	communication
		Design for six sigma	eng. tools
		Early supplier identification	process
		Engineering accountable for supplier management	process
		First samples off-tool 1 year before SOP	process
Manufacturing	Purchasing	Increase plant experience	miscellaneous
	Supplier	Collaboration of suppliers with assembly operators	communication
		Assembly operators review supplier designs	process
		Increase plant experience	miscellaneous
Sales & Marketing	Customer	Communication between customer and sales	communication

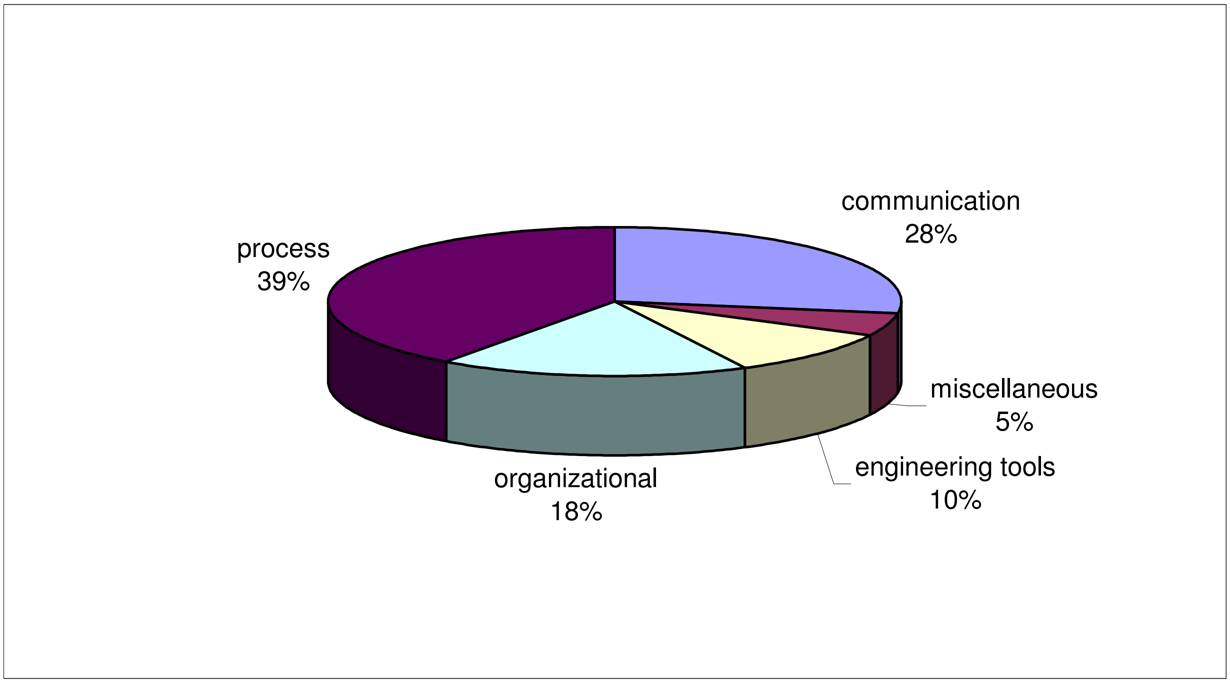


Figure 26. Percent of Enablers ranked in the stated Themes

Examination of Figure 26 and Table 21 clearly shows some of the major themes that have been running throughout the study, namely the importance of communication and the role a good process can play on ensuring communication. These results explain, in part, the emphasis organizations are placing on a disciplined product development process that ensures proper communication between various parties.

Some of the enablers presented by the panelists, such as “find common ground, find value in each others function, explain decisions” indicate to some degree the tension that exists between design and styling, and design and sales and marketing. The issues are of long standing and quite well known, and the results only point to the fact that they are still on-going. Design has difficulty communicating with styling the constraints placed upon them by manufacturing. And design would like better to understand styling’s decisions and their purpose. There appears to be a joint communication divide between styling and design that needs to be addressed, perhaps through better education of both sides.

Design also has difficulty when sales and marketing promise customers too much, be it in product features or delivery times. There was a suggestion to implement a more accurate quoting system. But, there are other issues as well, such as a better understanding of customer’s needs earlier in the design phase. Also, once the design cycle has begun, certain customer desires may be difficult to implement. Thus, managing the customer’s expectations and providing the communication between the customer and design, becomes critical.

Clearly as the speed to deliver timely information across the globe and organizational boundaries increases, so does our ability and desire to make effective decisions quickly. These changes show everyone where the gaps in human understanding and communication between the various functions in the value chain lie. It is hoped that this study will shed some light on this important topic and encourage discussion within the industry.

VII.3. Allocation of Developmental Resources

We asked the panelists which organization currently develops and is likely to develop vehicles in the future to get a sense for the movement of development resources among the various organizations. The organizations were identified by their Tier (OEM, Tier 1, contract houses, all others) and their geographic location (N.A., off-shore). Further the panelists were invited to respond to this movement of resources by subsystem. A panelist could respond to one or more subsystems.

The specific instructions were:

For the following question, please choose the system or systems you are most familiar with. Please identify the system by name in the column heading below. For more than two systems, please include additional pages.

Body	HVAC
Chassis / Suspension	Electrical / Electronics
Engine / Transmission	Test / Validation / Certification
Interior	Other (specify)

What percentage of product-design-and-development, in terms of percent of product development budget expended, do you think is currently performed and will be performed by each organization?

This question allowed multiple responses depending on the expertise of the respondents. Further, there were insufficient responses to answer each system separately. A system was analyzed if there were 5 or more responses. For those systems that had fewer than 5 responses, the responses were pooled into a single analysis called 'all other systems.' Thus, there is a separate analysis for interiors, engine/transmissions, chassis and suspension, body, and all other systems.

The results for each subsystem are presented below:

VII.3.a. Interiors

What percentage of product-design-and-development, in terms of percent of product development budget expended, do you think is currently performed and will be performed by each organization?

Table 22. Median and Quartile Scores for Allocation of Interior Development Resources.

	Median			Quartile (25/75)		
Organization	**2004**	**2009**	**2014**	**2004**	**2009**	**2014**
Vehicle manufacturer	20	15	10	20/20	14/20	8/20
N.A. suppliers (tier one)	40	35	30	30/40	30/40	30/45
Off-shore suppliers (tier one)	10	20	25	5/20	10/30	12/30
N.A. contract house	5	5	5	5/10	0/10	0/10
Off-shore contract house	5	5	5	0/5	0/8	0/12
N.A. suppliers (all other)	5	5	5	5/10	0/10	0/8
Off-shore suppliers (all others)	5	5	5	0/5	5/7	5/5

Selected Edited Comments:

- This is dependent on vehicle manufacturer. If NA, suppliers will be required to allocate more resources. If transplant, suppliers will be required to allocate fewer resources.

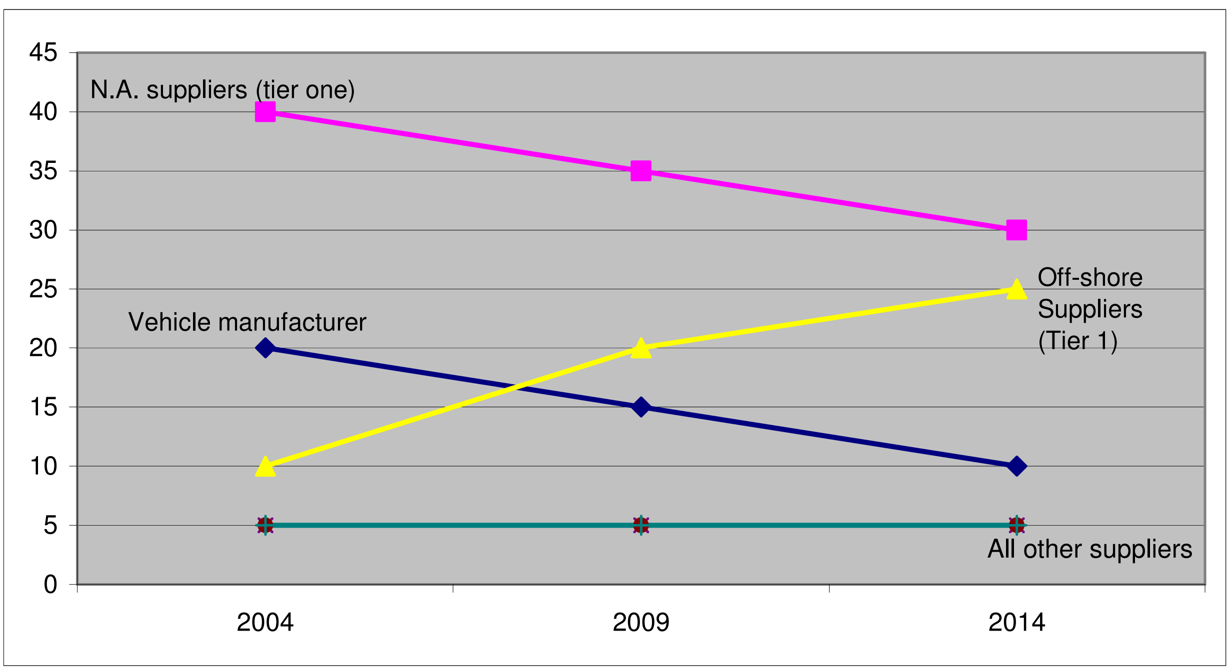


Figure 27. Median Trends for Allocation of Interior Development Resources.

Discussion and Strategic Considerations:

With regard to interiors, it is expected that both North American OEMs and Tier 1 suppliers will continue to outsource to off-shore Tier 1 suppliers. In 10 years, it is expected that only 10% of interior product development will be conducted by the OEMs and over half will be conducted by the NA and off-shore Tier 1 suppliers. However, it is not expected that there will be major changes in the lower tiers. In other words, there is no expectation that off-shore tiers will begin outsourcing or that NA Tier 1s will outsource to Tier 2s or higher suppliers in any significant way. This implies that the NA Tier 1 suppliers are outsourcing to the off-shore Tier 1 suppliers. All other suppliers are expected to retain a low 5% of interior development into the near and far future.

The IQR values indicate that the panel is in agreement over these general trends.

VII.3.b. Body and Chassis / Suspension

What percentage of product-design-and-development, in terms of percent of product development budget expended, do you think is currently performed and will be performed by each organization?

Table 23. Median and Quartile Scores for Allocation of Body/Chassis/Suspension Development Resources.

	Median			Quartile (25/75)		
Organization	**2004**	**2009**	**2014**	**2004**	**2009**	**2014**
Vehicle manufacturer	50	35	35	40/68	28/65	23/60
N.A. suppliers (tier one)	20	20	20	20/28	19/31	17/28
Off-shore suppliers (tier one)	5	10	15	5/8	8/15	10/20
N.A. contract house	5	5	5	5/9	4/8	2/5
Off-shore contract house	5	5	7	3/5	5/8	5/13
N.A. suppliers (all other)	5	4	3	1/5	0/5	0/5
Off-shore suppliers (all others)	1	5	5	0/5	0/5	0/5

Selected Edited Comments:

- I believe the shift to outsourcing has occurred and OEMs are reluctant to do more.

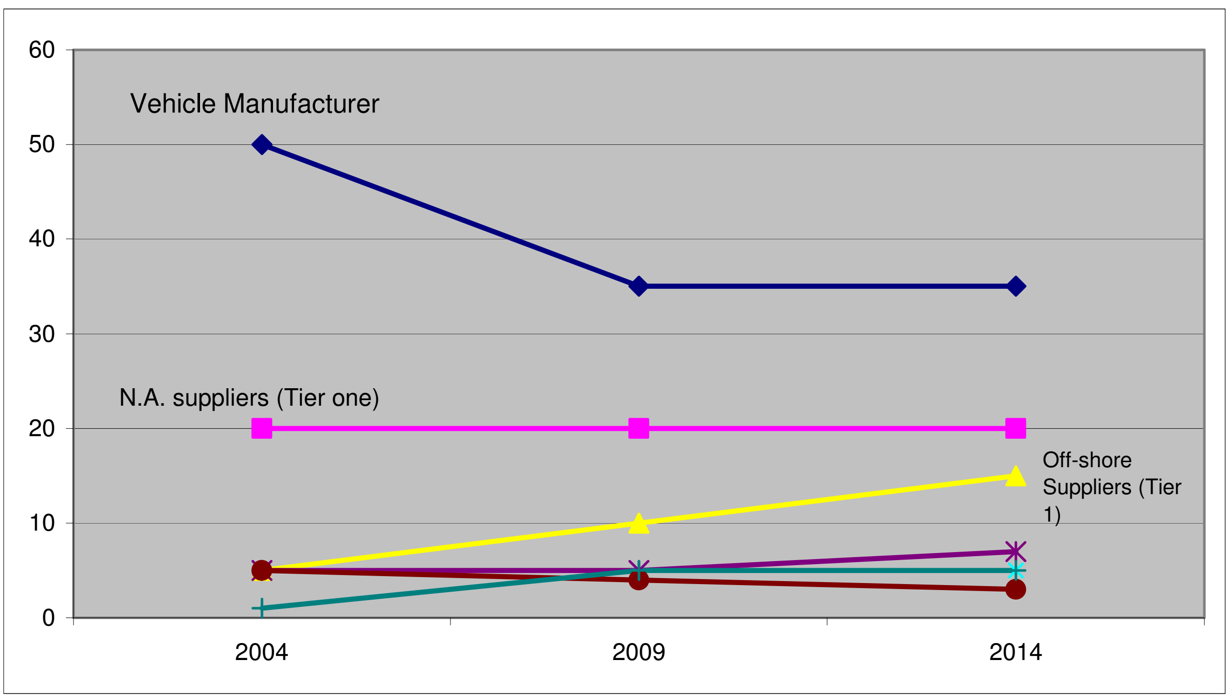


Figure 28. Median Trends for Allocation of Body/Chassis/Suspension Development Resources

Discussion and Strategic Considerations:
The situation is somewhat different with regard to bodies, chassis and suspension. The outsourcing trend evident in interiors is also evident here, albeit to a significantly lesser degree. The panel is split as to the degree to which the OEMs will outsource these various components, as evidenced by the extremely large quartile ranges of 40/68 to 23/60. Some of this split is due to the mixture of the body responses with the chassis and suspension responses, which was necessary due to a relatively small response rate. Chassis and suspension systems are expected to be outsourced, to some degree, over the next 10 years. The panel was very divided on the degree to which the body would be outsourced.

We view this as an indication of how the industry views the body as a major competitive battleground, and no one can predict how it will develop. Some believe that, to reduce costs, some OEMs will outsource major or all aspects of the body—particularly for low volume vehicles. Others believe OEMs desire to pull more work internal to their operations to keep their union employees working, as the organization has made productivity gains and is able to do more with less. Further, they believe that the automotive body is a major differentiator and a core competency that they must invest in further. The view that OEMs will not further outsource the body was expressed by one of the panelists.

Given the great variety of goals, capabilities, and opinions, as well as the technical and business complexity involving the body, the future may be unknown and unknowable.

VII.3.c. Engine/Transmission

What percentage of product-design-and-development, in terms of percent of product development budget expended, do you think is currently performed and will be performed by each organization?

Table 24. Median and Quartile Scores for Allocation of Engine/Transmission Development Resources

Organization	Median			Quartile (25/75)		
	2004	2009	2014	2004	2009	2014
Vehicle manufacturer	50	45	40	50/65	35/50	28/47
N.A. suppliers (tier one)	20	30	25	18/30	20/40	23/33
Off-shore suppliers (tier one)	5	10	20	3/15	15/15	15/23
N.A. contract house	5	5	5	1/8	8/1	1/8
Off-shore contract house	0	0	0	0/0	0/5	0/8
N.A. suppliers (all other)	0	0	0	4/0	0/4	0/4
Off-shore suppliers (all others)	0	0	0	0/0	0/1	0/2

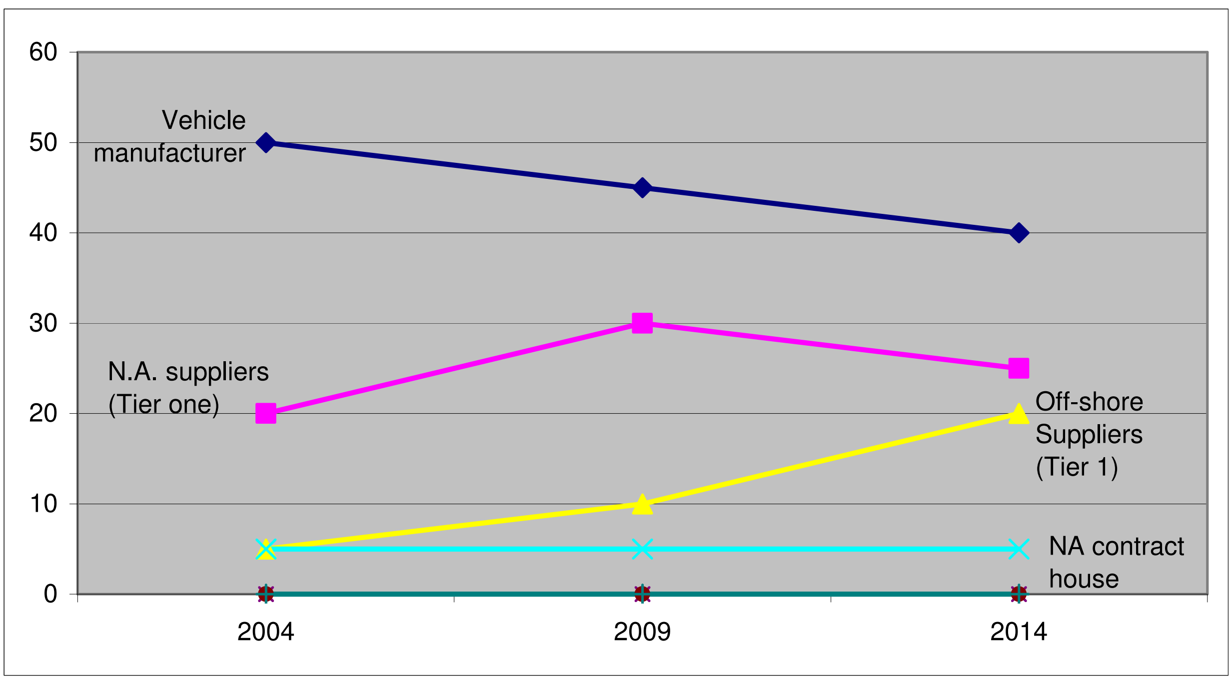


Figure 29. Median Trend of the Allocation of Engine/Transmission Development Resources

Discussion and Strategic Considerations:
OEMs will outsource powertrain systems and components to NA Tier 1s, at first. Then they, in turn, will start to outsource as well. Again, the major gainers are the off-shore Tier 1s. The

higher level tier suppliers, whether NA or off-shore, are not expected to expend any powertrain development resources. A small but stable amount of development will continue to be conducted by NA contract engineering houses.

Compared to the other two areas, the IQR scores are quite high, suggesting the panel is not in agreement as to the overall trends. Closer examination of the percentiles shows, however, that they follow the median trend. For example, the OEM median trend is decreasing, as is the trend for the 25th and 75th percentile. Thus, the panel is in agreement over the trends. They are less in agreement as to the absolute percentages attributable to each organization.

The cost of powertrain development is getting prohibitive–OEMs are collaborating more and more. The trend towards direct outsourcing is expected to continue as further cost reductions are necessary. Many OEMs, such as Ford and GM, DCX and Mitsubishi, and Toyota and Peugeot are collaborating through various types of partnerships to develop powertrains and transmissions that can be used globally on a variety of vehicle platforms. This trend is not only likely to continue with the OEMs, but may also trickle down to the Tier 1 and 2 suppliers, i.e., suppliers may begin collaboration in the powertrain area. This is possible from two trends, (1) powertrains are less of a product differentiator for the consumer, and (2) technology has enabled more variants of a basic powertrain to be developed.

The future of powertrains is uncertain with the rise of advanced diesel engines, hybrids, and progress in fuel cells. This uncertainty necessitates reducing the risk of future engine developments.

VII.4. Sources of Innovation

Please indicate the degree to which the following sources contribute to product and process innovations in your organization, that is, to generate creative and practical ideas now and for the future by allocating 100 points in each column.

Table 25. Median and Quartile Scores for Sources of Innovation.

Category	Median		Quartile (25/75)	
	2004	2009	2004	2009
Your organization internally	60	40	38/73	34/58
Competitive benchmarking	10	10	9/18	8/20
System suppliers	8	10	2/10	0/10
Material suppliers	8	5	1/10	3/10
Component suppliers	5	8	4/10	5/10
Independent researchers	5	5	0/7	1/5
Mfg process/tooling suppliers	1	5	0/5	3/6
Universities and gov't labs	1	5.5	0/5	4/10
Engineering service suppliers	0	5	0/5	0/5
Other industries outside automotive	0	0	0/1	0/5

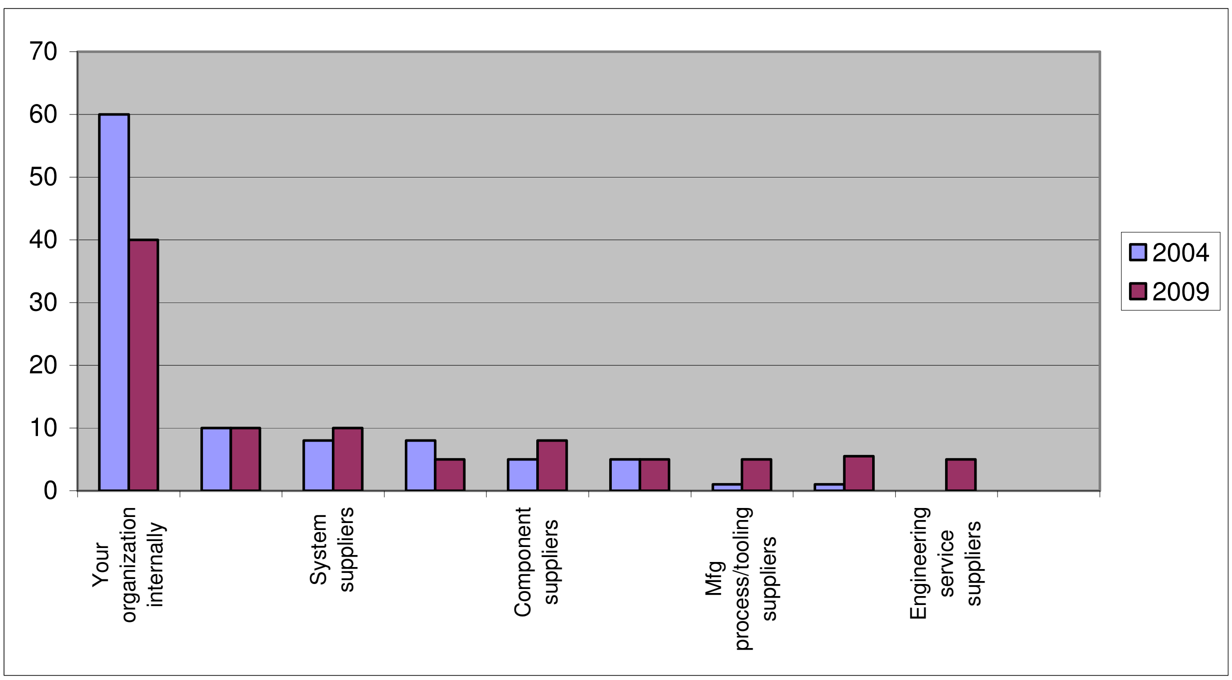


Figure 30. Median Trends for Sources of Innovation.

Selected Edited Comments:

- There are other sources: alliances and joint ventures.
- Best ideas and intellectual properties are from the inside.

- We have a strong internal strategy directed at Product Leadership and Engineering strength hence the internal bias

Discussion and Strategic Considerations:
Currently, approximately 70% of innovation is generated in-house and from competitive benchmarking. Slightly more than 20% is generated by the immediate supply community (systems, component, and material suppliers). Less than 10% is generated by other knowledge-based institutions (independent researchers, universities and government labs, engineering and manufacturing service suppliers).

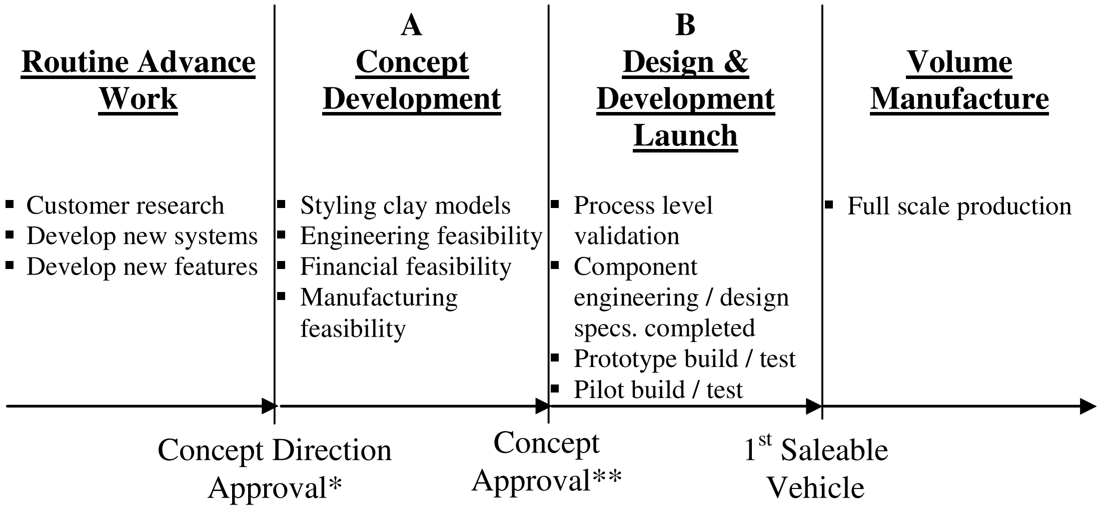
In the future, it is believed innovation will be generated from a broader base, with a reduction of in-house and competitive benchmarking to 50%; immediate suppliers will remain above 20%, and the other knowledge-based institutions will more than double to over 20%. These numbers do not necessarily sum to 100% because the analysis is based on median, not average, responses.

It is interesting to note the decrease in IQR from the current distribution to the forecasted distribution. This shows that while companies currently do things differently, there is grater consensus on what should be done in the future.

Many companies view innovation as a competitive advantage to stem the trend toward treating automotive products as commodities and the associated cost competition from lower labor producers that comes with it. Having that capability internal to the organization is recognized as being vitally important, as evidenced from some of the panel's comments. Companies, however, also realize that the knowledge is dispersed throughout the supply chain. While internal innovation is still vital and will continue to be the primary driver of product innovation, it cannot be the sole driver. The company that is most effective in tapping into the innovation resident in its supply base and society at large will have a significant advantage over its competitors.

VII.5. Development Time

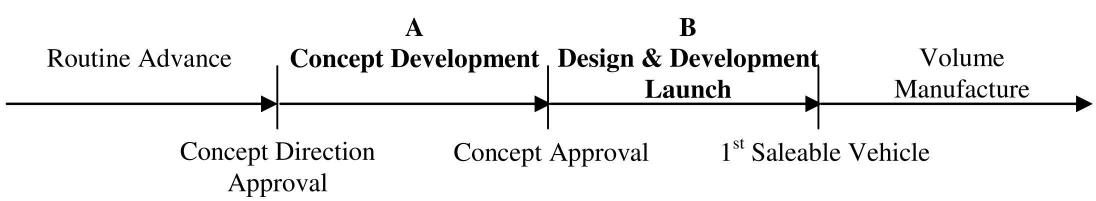
Please refer to the following diagram when responding to questions VII.5.a and VII.5.b. These questions ask you to estimate the time it takes to develop and launch an entire vehicle.



** Concept Direction Approval: The date that concept development resources and timing are approved.*

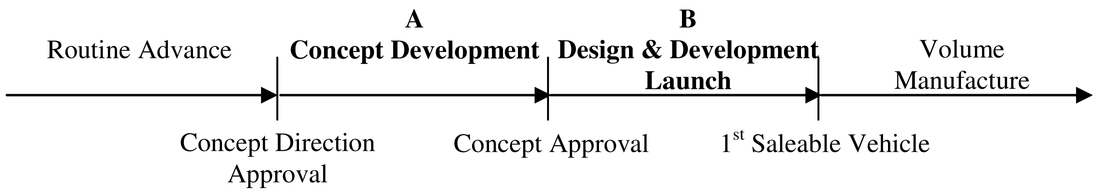
*** Concept Approval: Approval by corporate management to take the vehicle to volume production, including the commitment of money and human resources. This approval follows demonstration of a model of the vehicle, a demonstration vehicle, and a verification of manufacturability and financial viability of the program.*

For convenience, this abbreviated diagram is supplied with the questions.



The major difference between question VII.5.a and VII.5.b is the difference between the design and development effort of a new vehicle or a major redesign versus the effort of a reskinning or refreshing of an existing design. There are no hard and fast definitions of these two cases, and it will affect different parts of the industry in different ways. For the sake of these questions, the first case will be denoted new platform, and the second case will be denoted carryover platform.

VII.5.a. PD&D Development Time (New Platform)



Using the diagram above, please give your expectations, in months, for part "A" (Concept Development period) and part "B" (Design and Development period) of the vehicle development cycle. In this case, base your estimates on new platforms for high-volume vehicles (more than 50,000 units / year), by geographic area. Please estimate for current development cycles, and for development cycles in the year 2009 and 2014 for the manufacturers whose home base is in the geographic areas listed below (e.g., GM-Opel and Honda of America would be included in your estimates for North America and Japan, respectively).

Table 26. Median Scores for the Concept Development Time of a New Platform by Geographic Region from the 1998 Delphi and 2004 Delphi.

A: Concept Development--Median Response						
Geographic Region	**Number of Months Previous Delphi**			**Number of Months Current Delphi**		
	1998	**2002**	**2007**	**2004**	**2009**	**2014**
North America	16	13	12	12	12	12
Japan	14	12	10	11	10	9
Europe	17	15	12	12	10	10

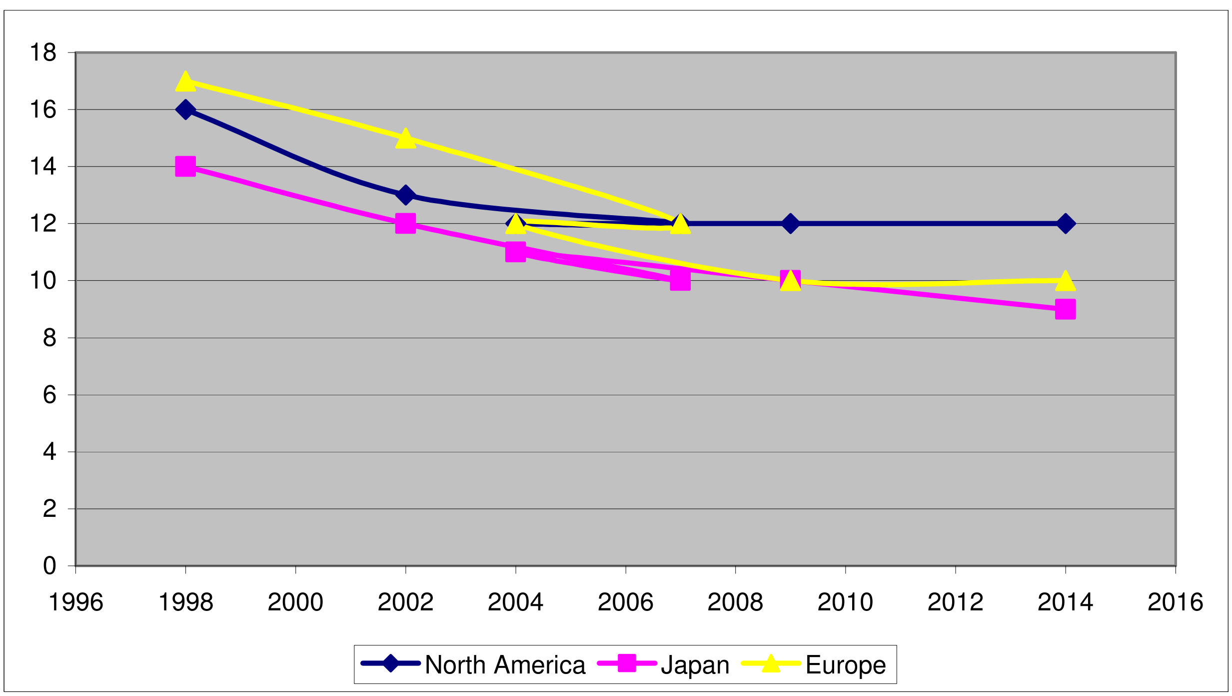


Figure 31. Median Trends for the Concept Development Time for New Platforms from the 1998 and 2004 Delphi.

Table 27. Median Scores for the Design, Development, and Launch Times of a New Platform by Geographic Region from the 1998 Delphi and 2004 Delphi.

B: Design, Development, & Launch--Median Response						
Geographic Region	Number of Months Previous Delphi			Number of Months Current Delphi		
	1998	2002	2007	2004	2009	2014
North America	29	24	18	24	20	18
Japan	24	20	16	18	16	14
Europe	30	24	20	20	19	16

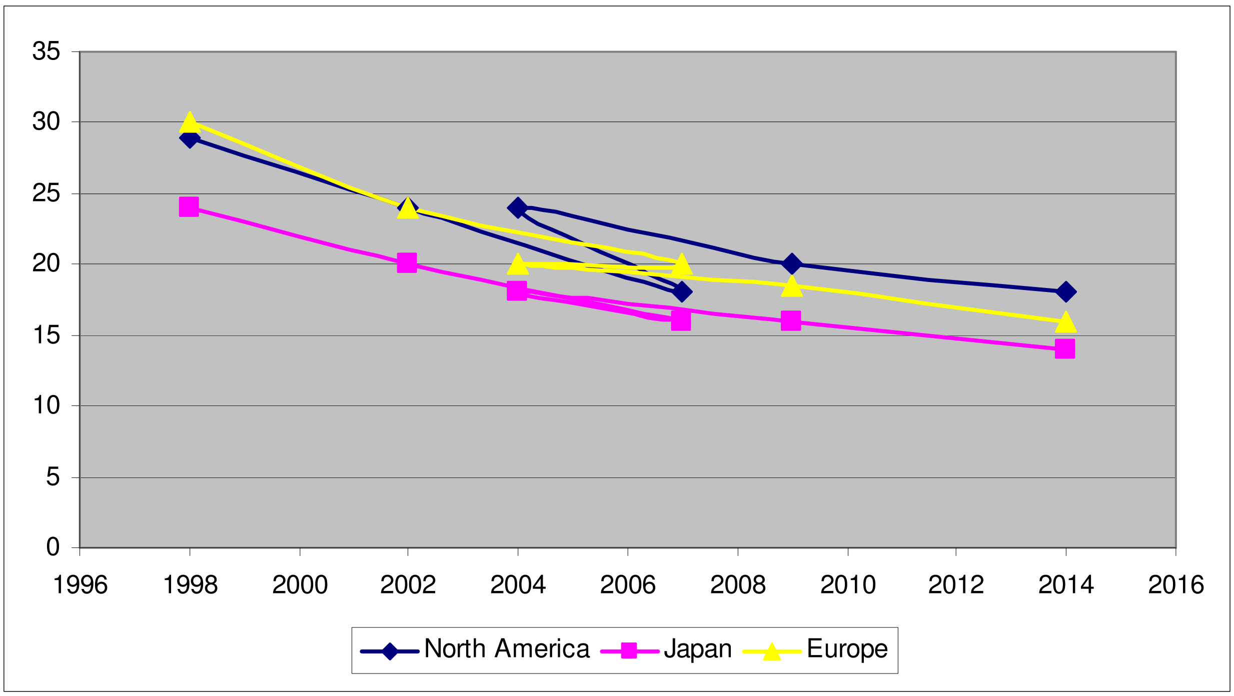


Figure 32. Median Trends of the Design, Development, and Launch Times for a New Platform from the 1998 and 2004 Delphi.

Table 28. Median Scores for the Total Development Time of a New Platform by Geographic Region from the 1998 Delphi and 2004 Delphi.

Total Time—Median Response						
Geographic Region	Number of Months Previous Delphi			Number of Months Current Delphi		
	1998	2002	2007	2004	2009	2014
North America	45	37	30	36	32	30
Japan	38	32	26	29	26	23
Europe	47	39	32	32	29	26

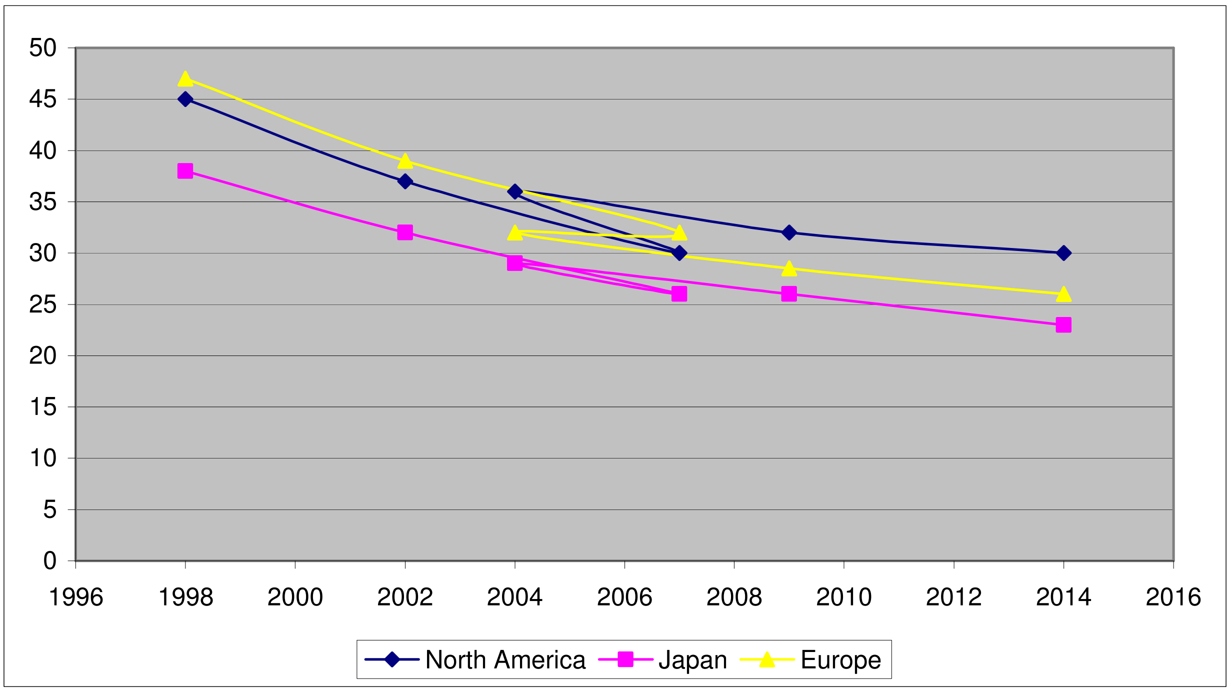


Figure 33. Median Trends for the Total Development Time of a New Platform from the 1998 and 2004 Delphi.

Select Edited Comments:

- The general belief is that our company could do substantially better on producing products over a compressed product development cycle if we were not micro-managed by the OEMs. Today, although we have the capabilities to provide innovative solutions, we are limited in what we can do because the OEMs really control the value chain and do not let the value chain perform as it really was designed to perform.

Discussion and Strategic Considerations:

The analysis of the product lead time consists of examining the times for parts A and B and the total time. Further, since the same question was in the 1998 OSAT study, a comparison of the results is also presented in the tables and graphs.

It should be noted that one OEM refused to answer this question citing proprietary and competitive information. The other OEM would only respond to NA and not estimate Japan or Europe. Thus, the results regarding Europe and Japan are purely from experts currently working at supplier facilities, although several of them had worked for OEMs previously.

With regard to the concept development lead time for a new platform vehicle, the NA estimate is consistent with the 1998 prediction and is expected to asymptote at 12 months. Japan will continue to be faster and further reduce its lead time to 9 months. The surprise is Europe, which is now perceived to be ahead of previous predictions and expected to catch up with the Japanese in the next 5 years.

One supplier is a niche vehicle producer. The combined viewpoint of the OEM and this supplier is that NA OEMs are significantly faster in Phase A of new vehicle design than the suppliers suggest (see Table 29). There is an approximate 4 month difference between the two estimates. Remembering that the study should not be compared to a traditional survey study, we believe the truth to be somewhere in between; US OEM development times are one to two months faster than indicated in Table 26 and Figure 31. Further, we believe the trend is to continue to reduce time in the system and it is not likely to asymptote to 12 months, but rather be reduced further in the future. This interpretation would place the NA Phase A times for new platform development at the same level as the Japanese.

Table 29. OEM and Supplier Comparison of NA Phase A Development Time for a New Platform.

Panelist Organization	2004	2009	2014
Supplier	14.0	12.0	12.0
OEM and Niche Vehicle Producer	10.0	8.0	6.0

With regard to the design, development, and launch time, NA is perceived to have fallen behind the previous prediction and be moving toward an 18-month launch. Japan is consistent with the 1998 prediction and moving towards a 14-month launch. Europe is perceived to be ahead of the 1998 prediction, and with the NA fall, has a much shorter launch time that is expected to approach 16 months.

The combined results for total product development time show that Japan is still the fastest. However, considering again the difference in Phase A estimates between suppliers and OEMs, this difference is no longer as significant. If one uses the OEM estimates for Phase A given in Table 29, then one obtains the graph shown in Figure 34. One notices, of course, that the total NA product development and launch time is reduced, compared to Figure 33.

In comparing the results with the previous OSAT study, one notices the following. First, Japan's perceived development time is relatively continuous, i.e., people's perception of Japanese capability and execution regarding product development time has remained consistent over the years. Second, the NA curve is now also consistent with the predictions from the previous study. Third, Europe has caught up with the NA in total product development time. Lastly, the gap between all competitors is expected to narrow considerably.

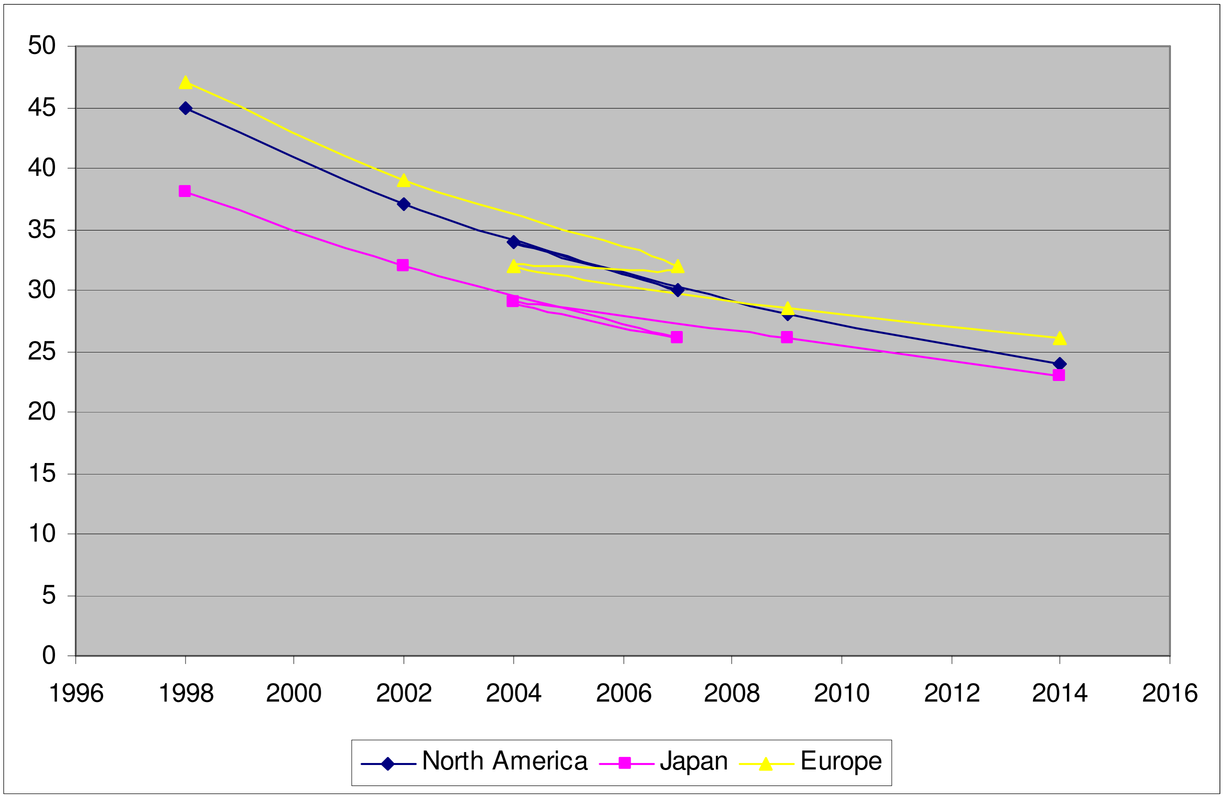
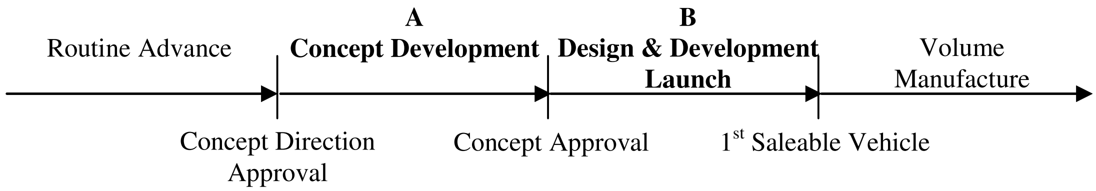


Figure 34. Median Trends for the Total Development Time of a New Platform from the 1998 and 2004 Delphi using the estimates in Table 29.

VII.5.b. PD&D Development Time (Carryover Platform)



Using the diagram above, please give your expectations, in months, for part "A" (Concept Development period) and part "B" (Design and Development period) of the vehicle development cycle. In this case, base your estimates on the hypothetical reskinning of high-volume vehicles (more than 50,000 units / year), carrying over the current platform. Please estimate for current development cycles, and for development cycles in the year 2009 for the manufacturers whose home base is in the geographic areas listed below (e.g., GM-Opel would be included in your estimates for the North America, and Honda of America would be included in your estimates for Japan).

Table 30. Median Scores for the Concept Development Time of a Carryover Platform by Geographic Region from the 1998 Delphi and 2004 Delphi.

A: Concept Development--Median Response						
Geographic Region	**Number of Months Previous Delphi**			**Number of Months Current Delphi**		
	1998	**2002**	**2007**	**2004**	**2009**	**2014**
North America	12	10	8	10	8	8
Japan	12	10	8	9	8	7
Europe	14	12	10	10	9	8

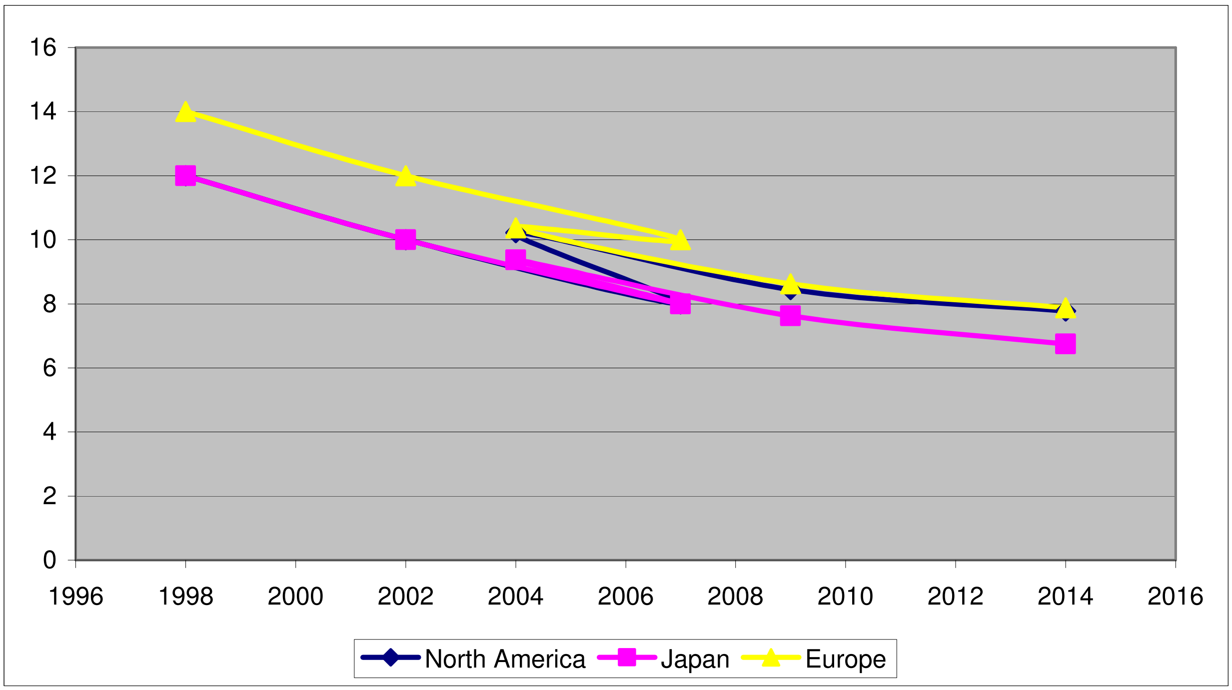


Figure 35. Median Trends for the Concept Development Time of a Carryover Platform from the 1998 and 2004 Delphi

Table 31. Median Scores for the Design, Development, and Launch Times of a Carryover Platform by Geographic Region from the 1998 Delphi and 2004 Delphi

B: Design & Development Launch—Median Response						
Geographic Region	**Number of Months Previous Delphi**			**Number of Months Current Delphi**		
	1998	**2002**	**2007**	**2004**	**2009**	**2014**
North America	24	19	16	16	14	13
Japan	18	16	12	13	11	11
Europe	24	20	16	15	14	13

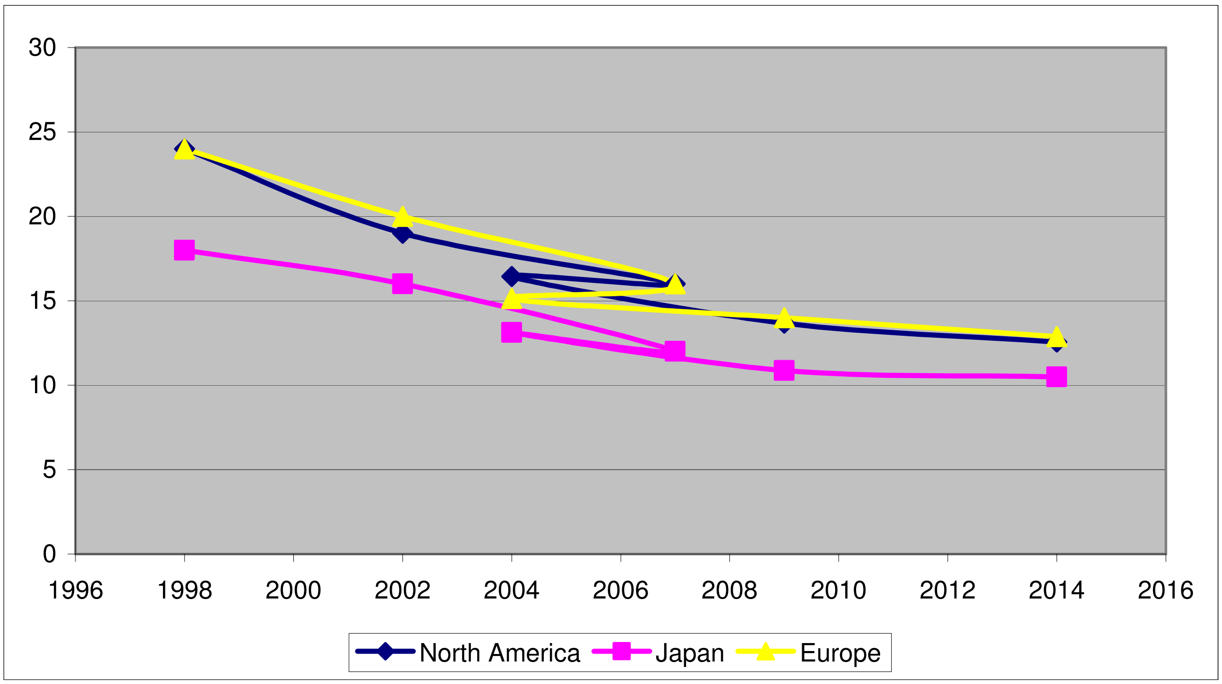


Figure 36. Median Trends for the Design, Development, and Launch Time of a Carryover Platform from the 1998 and 2004 Delphi

Table 32. Median Scores for the Total Development Time of a Carryover Platform by Geographic Region from the 1998 Delphi and 2004 Delphi

Total Time—Median Response						
Geographic Region	**Number of Months Previous Delphi**			**Number of Months Current Delphi**		
	1998	**2002**	**2007**	**2004**	**2009**	**2014**
North America	36	29	24	27	22	20
Japan	30	26	20	23	19	17
Europe	38	32	26	26	23	21

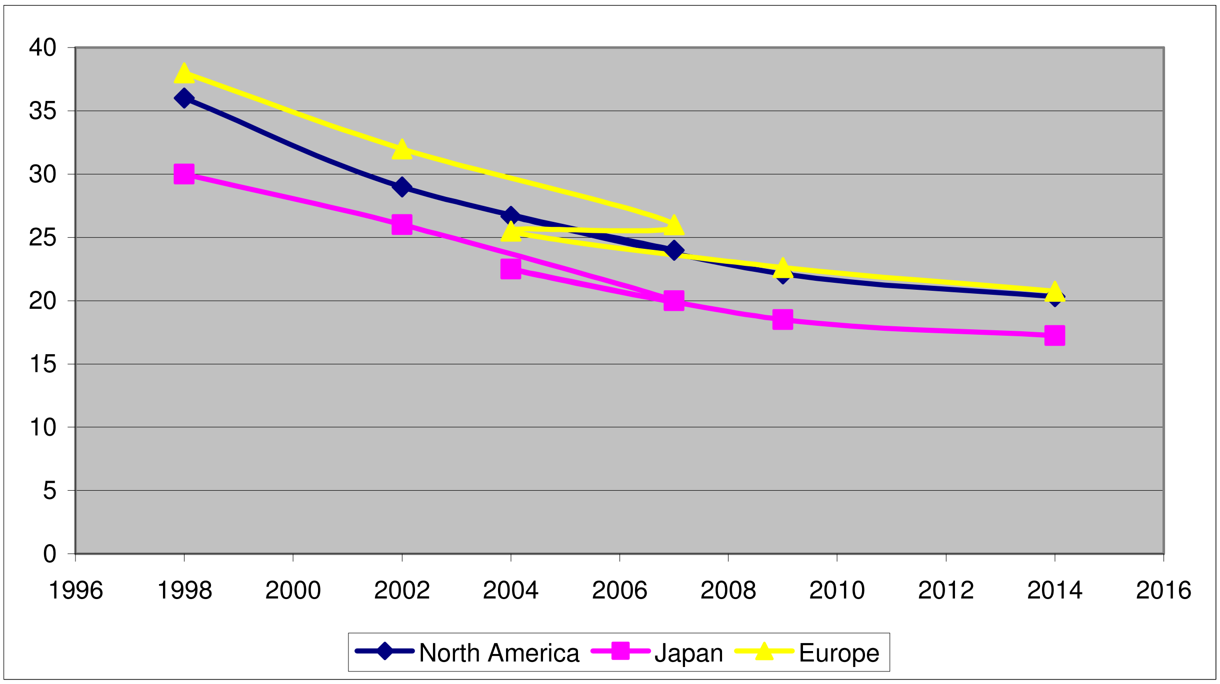


Figure 37. Median Trends for the Total Development Time of a Carryover Platform from the 1998 and 2004 Delphi

Discussion and Strategic Considerations:
The analysis of the product lead time consists of examining the times for parts A and B and the total time. Further, since the same question was on the 1998 OSAT study, a comparison of the results is also presented in the tables and graphs.

It should be noted that one OEM refused to answer this question citing proprietary and competitive information. The other OEM would only respond to NA and not estimate Japan or Europe. Thus, the results are purely from experts currently working as suppliers, although several of them had worked for OEMs previously. There was no different between the OEM and supplier estimates.

The NA forecast is lagging its 1998 prediction, and the European forecast is leading its 1998 prediction. Thus, for carryover platforms, the concept development time is approximately the same for NA and Europe, starting from the current 10 months and heading toward 8 months. The Japanese manufacturers are perceived to be about 1 month faster and are expected to maintain their lead.

The graph for development and launch shows a slightly different situation. Compared to the previous forecast, everyone is ahead of their forecast, and no one has changed their relative position. NA and Europe are considered to be approximately equally fast; the Japanese are about 3 months faster. However, when one looks at the overall trends, one can see that the gap between the various manufacturers is narrowing. Also, there appears to be a belief that there is a limit on how short a time one can launch a vehicle. The Japanese are expected to asymptote around 11 months.

The total lead time reflects both of these effects. The Europeans have caught up with NA—both are about 3 months behind the Japanese, who are expected to continue to lead the industry in being able to introduce new carryover vehicles quickly. This gap is not expected to narrow significantly over the next 3 years.

VII.5.c. Tool Release Time

Final drawing release (the date when the product design is considered complete, such that manufacture of production tooling may begin) occurs sometime during phase B. In your experience, when in phase B does the final drawing release currently occur, and when will it occur in the future? Please state your answer as a percent of phase B, for example: 25%, 50%, or 75% into Phase B.

Table 33. Median and IQR scores for Tool Release Time.

	Median		Quartile (25/75)	
	2004	**2009**	**2004**	**2009**
% into phase B	80	50	66/90	50/60

Selected Edited Comments:

- The ability to coordinate design changes is getting better. Assuming databases are "up to date", improved MBE capabilities will reduce engineering changes and increase virtual testing.
- A tool needs to be released to support production. The question is: How many times did the tool change after its initial release?

Discussion and Strategic Considerations:

The purpose of the question was to shed some light on the debate about whether tooling release should occur later in a program allowing design to include as many changes as possible prior to tool release or have tooling release earlier allowing manufacturing sufficient time to launch the new product. As seen in the comments, the issue of engineering changes is core to the discussion. The median trend is clearly showing that tooling release time will occur earlier in the product development cycle than it is currently. While the IQR shows some disagreement among the respondents as to the current point when tooling release occurs during the product development cycle, the panel appears to have achieved a consensus that it will occur approximately 50% into phase B.

One should state that the percentage mentioned is likely to be an average for a vehicle program. As with all products, there are some long lead time items which would need to be released much earlier. Similarly, there are short lead time items that are either inexpensive to change or unlikely to change.

The response that tooling release will occur earlier is consistent with three other trends. First is the improvement in global communication and coordination across all organizational boundaries, including between customers and suppliers. This trend has a tremendous impact on the entire system's ability to respond to design changes, even late in the program. Second, the time to complete phase B has been shortening rapidly over the last 5 years and is expected to continue to do so (see Section VII.5. Development Time). Since manufacturing requires a fixed set of time to launch a new product, tooling release will have to occur earlier within phase B. Third, the industry is working diligently on methods to reduce the number of late changes in a program. While the industry is clearly not there yet, there may be some expectation among the respondents that this situation will improve or at least be better managed, thereby allowing an earlier tool release date.

VII.6. Barriers in Product Development Cycle

The panelists were asked to:

Please list the three most important barriers that reduce the effectiveness of your product development cycle.

Each respondent listed three different barriers ranked by importance: 1, 2, and 3. The 33 ranked barriers (3 responses from 11 panelists), were then examined and grouped according to similar themes. The resulting seven categories and the verbatim barriers are given below. The ranking of each barrier is also indicated in front of each barrier. The highest priority ranking is 1 and the lowest is 3. From the individual barrier rankings it is possible to compute an average ranking for each category. This is given in parentheses behind each category name.

Another measure of the importance of a particular barrier category is the frequency with which it was mentioned. Figure 38 shows the frequency of each category as a percent of total responses. The average ranking and frequency are independent measures of the importance of a particular barrier category. Thus, for example, the highest ranked category was program management, with an average ranking of 1.6 and accounted for 17% of the total barriers mentioned. In contrast the most comments (27%) were in the customer category; its overall average ranking was 1.88.

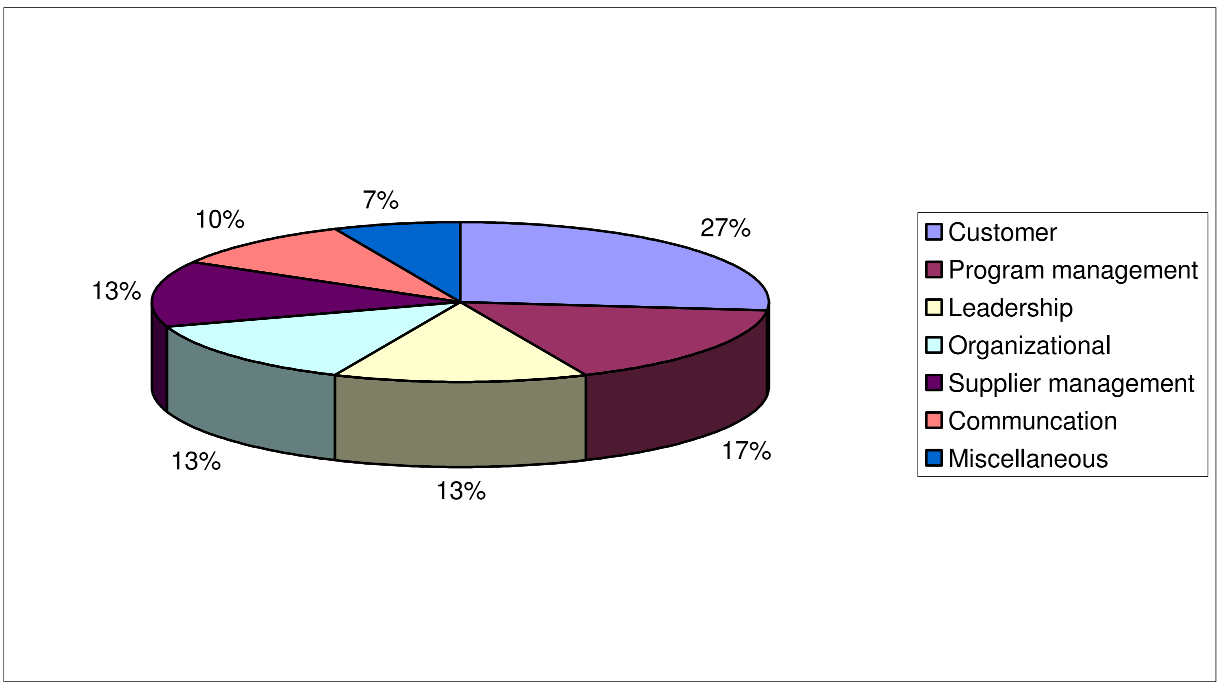


Figure 38. Percent of Total Responses.

Program Management (1.60)

1. Assessment of technical gaps and needs that complete a robust solution.

1. Lack of detailed program plans.
1. Delays in obtaining approvals.
2. Insufficient skill sets at the appropriate times.
3. Inability to investigate impact of tradeoff decisions.

Leadership (1.75)

1. Non-common goals of the parties involved.
1. Lack of complete Requirements definition up front in the program.
2. Lack of firm decisions.
3. Prioritization of programs.

Supplier Management (1.75)

1. Compressed product development timelines with late involvement by suppliers that require innovation or R&D imbedded in the timeline and contain ongoing/never-ending engineering changes.
1. Ineffective supplier base management.
2. Supplier quality issues.
3. Supplier participation and contributions that add value.

Customer (1.88)

1. Late release of customer requirements.
1. Late customer changes.
2. Customer requirement/content changes.
2. Customer decision time.
2. Receive purchase orders late causing delays in program start dates placing programs in jeopardy immediately.
2. Changes in direction downstream from design freeze.
2. Customer-driven program changes during the program.
3. Unwillingness of customer to help fund value-added development and innovation while forcing Tier 2s to always go through Tier 1s. This causes Tier 2s to never realize the value of their innovation which in turn offers the Tier 2s no protection with respect to being able to keep the work for an extended period of time and recover their product development investment.

Miscellaneous (2.0)

1. Market changes.
3. Time to market.

Communication (2.3)

2. Functional collaboration/effective communication.
2. Interaction and collaboration b/t eng. and mfg.
3. Difficulty in scheduling meetings (web or face-to-face) given global locations and more importantly people's schedules

Organizational (3.0)

3. Capability for first time quality/capability of designs (no failures).
3. Organization changes.
3. Non-standard global manufacturing, driving proliferation of design for manufacture
3. Test cycles. Synchronized process logic.

Discussion and Strategic Considerations:
Compared to the 1998 study some of the major categories and the barriers have stayed the same, while others have changed significantly. For example, barriers relating to global interactions, cultural differences, etc. that were prevalent in 1998, are no longer so. The issues regarding leadership and lack of understanding still exist today, as they did in 1998. However, previous comments directed many barriers inward, i.e., problems with internal communication, leadership, and organizational structure. The barriers in the current Delphi have a stronger external focus than before.

The major barriers appear to be in the area of project management (score of 1.6). 17% of the comments were in this area (second highest frequency) and most ranked it a high priority concern. A program management barrier is related to the required resources, timing, and coordination of events that must occur for a successful project. Related to this is the leadership barrier. It was the second most important (score of 1.75) and third most frequent (13%) barrier. Leadership is different from program management in that it involves decision making and team management (motivation).

The area of supplier management was tied with leadership. Related to this is the category of customer, which had the largest proportion of responses. The two together, representing the customer supplier relationship, account for 40% of the total responses. This is a far greater percentage than the comments seen in the 1998 study. We believe this reflects the outsourcing trend that was predicted in the 1998 study. We have now seen this trend occur; it is expected to continue and become more global. Thus, the major conclusion is that customers and suppliers must address each others concerns with regard to timing, innovation, and project management, to become globally successful.

VII.7. PD&D Miscellaneous

Please comment on any other major contributors or trends which might change future product development cost and times.

The panelists were very generous with their comments in this section; many reflected some of the themes of communication and collaboration that have been presented in previous sections, and thus will not be repeated here. There were also several comments regarding the increased use of computer simulation, which has also been discussed elsewhere in the study.

The comments selected below are believed to reflect issues that have not been raised elsewhere or elaborate on a topic and point to significant issues in the industry that have an impact on product design. In some cases there were several panelists who made similar comments.

Selected Edited Comments:

- Outsourcing of niche/low volume vehicles is a major issue.
- The increased education of designers is important.
- We continue to see a lot of intellectual property that is developed by suppliers being literally taken away from them and handed to the customers (Tier 1s and/or OEMs). It's hard for the supply chain to make a profit when the effort involved in developing innovation is not valued. There is an ongoing shift in creativity from OEMs to Tier 1s and now on to Tier 2s. The Tier 2s have tremendous value to offer and can provide innovation in a cost-effective manner with compressed time frames. These are the same Tier 2s that are being controlled and subsequently damaged by the OEMs. Going forward, many Tier 2s may be more selective in who they work with or potentially may take their innovation to other markets where they can make a reasonable profit. There may also be opportunity with the New Domestics (Transplants) as they are seemingly a bit more respectful of their supply chain and truly value the innovation they bring.

As shown in section 0. Design also has difficulty when sales and marketing promise customers too much, be it in product features or delivery times. There was a suggestion to implement a more accurate quoting system. But, there are other issues as well, such as a better understanding of customer's needs earlier in the design phase. Also, once the design cycle has begun, certain customer desires may be difficult to implement. Thus, managing the customer's expectations and providing the communication between the customer and design, becomes critical.

Clearly as the speed to deliver timely information across the globe and organizational boundaries increases, so does our ability and desire to make effective decisions quickly. These changes show everyone where the gaps in human understanding and communication between the various functions in the value chain lie. It is hoped that this study will shed some light on this important topic and encourage discussion within the industry.

Allocation of Developmental Resources outsourcing to the supply chain is expected to continue. While not raised in the study, there are issues associated with niche or low volume vehicles. As they often cannot be profitably manufactured by OEMs due to lack of manufacturing flexibility or cost structure that is unable to defray the development and production costs, these types of vehicles are often outsourced. The market is continuing to fragment as evidenced by the increasing number of vehicle models and vehicle types, the latest of which are "cross-over" vehicles. This commoditization of the automobile challenges the industry to find more cost-efficient ways to produce relatively low volumes of particular vehicle models. This effort is likely to present challenges not only to how the vehicle is produced, but also to how the vehicle and production system are designed and launched.

The issue of increasing the education of designers touches on several topics. First, it could be related to the rapid change in technology, implying that many engineers are not keeping up with what is being developed for their application domain. This would include product technology and also design analysis methods, such as value analysis. Second, it could be related to collaboration with other groups, e.g., it is necessary to educate designers about the manufacturing process and systems so that they will be able to improve the quality of their designs. This was one theme that was evident in section VII.2.b. Enablers for increased interactions. Third, it may be an indication of how the engineer's role has changed over the last decade from a product or process designer to a project manager since more and more of the design is being outsourced. In that regard, there was a comment that creating engineers responsible for supplier management would enable collaboration between a customer's design team and the supplier. Lastly, it may be an indictment of the higher education system in the United States. There have been calls from industry to change the manner in which engineers are taught at the nation's universities so that their skills better meet industries' needs.

The final comment addresses the customer supplier relationship—a subject that has come under increasing industry attention in the last two years. This comment was selected from several that were provided throughout the study, as it appeared to be representative of a general feeling expressed by several of the panelists. In recent years, it has been reported in the media that, as the domestic OEMs have come under increasing competitive pressures, they have pressured their supply chain. In some cases, they have implemented practices that create an antagonistic (as opposed to collaborative) relationship. The impression is that the transplants have a better relationship with their supply chain. That impression was echoed by some of the panelists as well.

Several factors have contributed to the situation. First, the domestic OEMs are fighting for survival and the cost pressures they experience are being passed on to the supply chain. This was echoed by the panel by stating product cost as the most important supplier attribute (see IV.3. Impact of Supplier Capabilities). This factor is not expected to change in the future. Second, the OEMs are becoming more efficient in all areas of their operations, evidenced by the narrowing gap in lead time reduction (see VII.5. Development Time). Further, with greater efficiency, they can do more with less. Thus, OEMs may outsource less in certain areas, such as bodies, running counter to the supply chain expectation (see VII.3.b. Body and Chassis / Suspension).

We believe the industry will undergo a structural change. As more companies become more efficient, and without a significant increase in market demand in the local geographic markets, the current capacity in the supply base will necessarily shrink.

The whole topic of the customer-supplier relationship and supply chain management is of critical importance. Collaboration and communication, both in terms of the technology as well as in terms of increasing understanding between disparate groups, has been a major theme that has been touched upon by the panel repeatedly throughout the study. While more and more of the vehicle is being outsourced to the supply base, media reports of collaboration tend to be between competitors. This collaboration is particularly true in the powertrain area—exemplified by GM and Ford collaborating on transmissions, GM and DCX on hybrid technology, or Toyota and PSA on a joint engine. Fewer, if any, reports exist on vertical collaboration with the supply chain.

Yet, the panel recognizes the need for better communication and earlier involvement (i.e., collaboration) of the supply chain, particularly in the area of product design and manufacturing, if the whole system is to reap further gains in efficiency and shorter product lead times. And in Section VII.2.b. Enablers for increased interactions, panelists mention some suggestions as to how communication could be improved. But these types of changes, while a start, are clearly insufficient to address the broader customer-supplier relationship issue. And while supplier relationships and supplier management have a profound effect on product design by the mere fact that more and more of the vehicle is being outsourced, it is beyond the scope of this study to investigate and address these issues in detail.

We encourage the industry to open a dialogue to address this important issue.

VIII. Appendix: Median Scores and Quartiles for all Factors by Vehicle System and Communication Method.

VIII.1 Scenario 1: Influence of Design Criteria on Interiors and Communication Methods within an Organization

VIII.2 Scenario 2: Influence of Design Criteria on Interiors and Communication Methods within the Supply Chain

VIII.3 Scenario 3: Influence of Design Criteria on Interiors and Communication Methods with the Customer

VIII.4. Scenario 4: Influence of Design Criteria on Body and Communication Methods within the Organization

VIII.5. Scenario 5: Influence of Design Criteria on Body and Communication Methods within the Supply Chain

VIII.6. Scenario 6: Influence of Design Criteria on Body and Communication Methods with the Customer

VIII.7. Scenario 7: Influence of Design Criteria on Engines/Transmissions and Communication Methods within the Organization

VIII.8. Scenario 8: Influence of Design Criteria on Engines/Transmissions and Communication Methods within the Supply Chain

VIII.9. Scenario 9: Influence of Design Criteria on Engines/Transmissions and Communication Methods with the Customer

VIII.1. Scenario 1: Influence of Design Criteria on Interiors and Communication Methods within an Organization

Area	Category	Median		Quartile (25/75)	
		2004	**2009**	**2004**	**2009**
Business Philosophy	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
	Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
	Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
	Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
	Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
	Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
	Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1
Organizational Factors	Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
	Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
	Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
	Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
	Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
	Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
	Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
	Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
	Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2
Supplier	Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
	Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
	High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
	Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
	CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3
	Systems integration capabilities (system interaction expertise, full service support, “black box” capability)	0.0	0.1	0.0/0.9	0.0/0.8

VIII.1. Scenario 1: Influence of Design Criteria on Interiors and Communication Methods within an Organization

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Supplier	Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Design Methods	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
	Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
	Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
	Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
	Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
	Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
	Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
	Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7
Design Tools	Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
	Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
	Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
	Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
	Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
	Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
	Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
	Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
	Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
	Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
	Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
	Clay models	0.0	0.0	0.1/0.9	0.3/1.1
	Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
	Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0
Design Criteria	Final product cost	2.8	2.0	2.1/3.0	1.8/2.7
	Aesthetics / styling	1.4	1.7	1.2/1.6	0.9/2.5
	Available product development time / budget	1.4	1.4	1.2/6.0	0.8/1.9
	Product safety / liability	1.3	1.2	1.1/1.5	0.8/1.4
	Product quality, reliability, and durability	0.8	0.9	0.8/1.8	0.8/0.9
	Standardized designs of parts & subsystems; library of design concepts, design templates	0.8	1.5	0.7/4.2	0.8/3.9
	Product mass	0.8	0.9	0.7/2.1	0.8/2.0
	Government regulations	0.8	0.8	0.0/0.8	0.0/1.0
	Packaging constraints	0.8	0.5	0.6/1.1	0.0/1.0
	Ease of manufacture and assembly	0.7	0.8	0.6/0.8	0.5/0.9
	Recyclability	0.7	0.8	0.0/0.8	0.5/0.8
	Ease of service/cost of repair	0.7	0.4	0.0/0.8	0.0/0.9
	Product specific performance characteristics	0.6	0.5	0.0/1.1	0.0/1.4
Communication Methods	Electronic communication (i.e., internet / email / ftp)	4.2	4.5	3.4/4.5	3.6/6.0
	Physical face-to-face meetings	3.0	2.0	1.9/4.8	1.4/3.5
	Co-location within a common work area	1.8	1.7	0.9/2.3	1.6/2.8

VIII.1. Scenario 1: Influence of Design Criteria on Interiors and Communication Methods within an Organization

Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
Communication Methods	Print-based communication (memos, letters, reports, Overnight mail etc.)	1.5	0.7	0.9/2.0	0.2/1.3
	Interactive computer tools and use of common databases	1.2	1.4	0.4/2.1	0.7/2.9
	Voice mail and fax	1.1	1.2	0.9/2.3	0.9/2.4
	Video conferencing	0.7	1.0	0.3/1.1	0.8/1.4
	Web-based collaboration tools	0.3	1.5	0.0/1.1	0.4/1.9
	Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.7	0.0/0.8
Human resource management	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
	Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
	Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
	Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
	Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
	Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
	Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
	Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1

VIII.2. Scenario 2: Influence of Design Criteria on Interiors and Communication Methods within the Supply Chain

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Business Philosophy	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
	Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
	Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
	Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
	Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
	Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
	Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1
Organizational Factors	Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
	Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
	Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
	Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
	Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
	Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
	Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
	Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
	Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2
Supplier	Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
	Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
	High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
	Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
	CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3
	Systems integration capabilities (system interaction expertise, full service support, “black box” capability)	0.0	0.1	0.0/0.9	0.0/0.8

VIII.2. Scenario 2: Influence of Design Criteria on Interiors and Communication Methods within the Supply Chain

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Supplier	Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Design Methods	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
	Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
	Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
	Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
	Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
	Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
	Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
	Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7
Design Tools	Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
	Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
	Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
	Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
	Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
	Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
	Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
	Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
	Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
	Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
	Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
	Clay models	0.0	0.0	0.1/0.9	0.3/1.1
	Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
	Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0
Design Criteria	Final product cost	2.8	2.0	2.1/3.0	1.8/2.7
	Aesthetics / styling	1.4	1.7	1.2/1.6	0.9/2.5
	Available product development time / budget	1.4	1.4	1.2/6.0	0.8/1.9
	Product safety / liability	1.3	1.2	1.1/1.5	0.8/1.4
	Product quality, reliability, and durability	0.8	0.9	0.8/1.8	0.8/0.9
	Standardized designs of parts & subsystems; library of design concepts, design templates	0.8	1.5	0.7/4.2	0.8/3.9
	Product mass	0.8	0.9	0.7/2.1	0.8/2.0
	Government regulations	0.8	0.8	0.0/0.8	0.0/1.0
	Packaging constraints	0.8	0.5	0.6/1.1	0.0/1.0
	Ease of manufacture and assembly	0.7	0.8	0.6/0.8	0.5/0.9
	Recyclability	0.7	0.8	0.0/0.8	0.5/0.8
	Ease of service/cost of repair	0.7	0.4	0.0/0.8	0.0/0.9
	Product specific performance characteristics	0.6	0.5	0.0/1.1	0.0/1.4
Communication Methods	Electronic communication (i.e., internet / email / ftp)	4.2	3.8	2.8/6.3	3.1/7.2
	Physical face-to-face meetings	2.3	2.1	2.1/3.6	1.5/2.8
	Co-location within a common work area	0.0	0.9	0.0/0.6	0.0/1.6

VIII.2. Scenario 2: Influence of Design Criteria on Interiors and Communication Methods within the Supply Chain

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Communication Methods	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.1	1.5	0.7/3.4	0.5/2.0
	Interactive computer tools and use of common databases	1.3	1.1	0.5/1.5	0.2/2.8
	Voice mail and fax	2.5	2.0	1.3/2.9	1.3/3.1
	Video conferencing	0.5	0.9	0.0/0.7	0.2/1.5
	Web-based collaboration tools	0.8	1.5	0.0/1.4	0.8/1.8
	Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.6	0.0/1.4
Human resource management	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
	Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
	Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
	Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
	Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
	Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
	Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
	Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1

VIII.3. Scenario 3: Influence of Design Criteria on Interiors and Communication Methods with the Customer

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Business Philosophy	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
	Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
	Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
	Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
	Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
	Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
	Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1
Organizational Factors	Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
	Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
	Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
	Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
	Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
	Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
	Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
	Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
	Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2
Supplier	Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
	Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
	High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
	Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
	CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3
	Systems integration capabilities (system interaction expertise, full service support, “black box” capability)	0.0	0.1	0.0/0.9	0.0/0.8

VIII.3. Scenario 3: Influence of Design Criteria on Interiors and Communication Methods with the Customer					
Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
Supplier	Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Design Methods	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
	Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
	Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
	Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
	Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
	Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
	Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
	Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7
Design Tools	Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
	Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
	Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
	Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
	Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
	Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
	Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
	Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
	Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
	Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
	Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
	Clay models	0.0	0.0	0.1/0.9	0.3/1.1
	Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
	Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0
Design Criteria	Final product cost	2.8	2.0	2.1/3.0	1.8/2.7
	Aesthetics / styling	1.4	1.7	1.2/1.6	0.9/2.5
	Available product development time / budget	1.4	1.4	1.2/6.0	0.8/1.9
	Product safety / liability	1.3	1.2	1.1/1.5	0.8/1.4
	Product quality, reliability, and durability	0.8	0.9	0.8/1.8	0.8/0.9
	Standardized designs of parts & subsystems; library of design concepts, design templates	0.8	1.5	0.7/4.2	0.8/3.9
	Product mass	0.8	0.9	0.7/2.1	0.8/2.0
	Government regulations	0.8	0.8	0.0/0.8	0.0/1.0
	Packaging constraints	0.8	0.5	0.6/1.1	0.0/1.0
	Ease of manufacture and assembly	0.7	0.8	0.6/0.8	0.5/0.9
	Recyclability	0.7	0.8	0.0/0.8	0.5/0.8
	Ease of service/cost of repair	0.7	0.4	0.0/0.8	0.0/0.9
	Product specific performance characteristics	0.6	0.5	0.0/1.1	0.0/1.4
Communication Methods	Electronic communication (i.e., internet / email / ftp)	4.2	4.4	3.8/6.0	3.2/8.0
	Physical face-to-face meetings	2.8	2.0	2.1/3.2	1.4/3.2
	Co-location within a common work area	0.5	1.5	0.2/1.2	0.0/1.6

VIII.3. Scenario 3: Influence of Design Criteria on Interiors and Communication Methods with the Customer

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Communication Methods	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.6	0.8	0.8/3.6	0.3/1.8
	Interactive computer tools and use of common databases	1.2	1.4	0.3/1.5	0.4/3.0
	Voice mail and fax	1.5	1.6	1.3/3.5	0.8/2.6
	Video conferencing	0.5	0.8	0.0/0.8	0.4/1.0
	Web-based collaboration tools	0.8	1.6	0.0/1.3	0.8/2.3
	Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.5	0.0/1.1
Human resource management	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
	Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
	Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
	Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
	Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
	Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
	Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
	Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1

VIII.4. Scenario 4: Influence of Design Criteria on Body and Communication Methods within the Organization

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Business Philosophy	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
	Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
	Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
	Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
	Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
	Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
	Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1
Organizational Factors	Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
	Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
	Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
	Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
	Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
	Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
	Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
	Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
	Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2
Supplier	Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
	Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
	High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
	Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
	CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3
	Systems integration capabilities (system interaction expertise, full service support, “black box” capability)	0.0	0.1	0.0/0.9	0.0/0.8

VIII.4. Scenario 4: Influence of Design Criteria on Body and Communication Methods within the Organization

Area	Category	Median		Quartile (25/75)	
		2004	**2009**	**2004**	**2009**
Supplier	Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Design Methods	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
	Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
	Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
	Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
	Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
	Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
	Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
	Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7
Design Tools	Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
	Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
	Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
	Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
	Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
	Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
	Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
	Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
	Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
	Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
	Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
	Clay models	0.0	0.0	0.1/0.9	0.3/1.1
	Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
	Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0
Design Criteria	Final product cost	2.1	2.0	0.8/2.8	1.0/2.7
	Aesthetics / styling	1.4	1.5	1.3/1.5	0.7/1.9
	Available product development time / budget	1.3	1.7	0.0/1.4	0.0/1.7
	Product safety / liability	1.1	1.2	1.0/1.3	1.2/1.4
	Product quality, reliability, and durability	0.9	0.9	0.8/1.0	0.9/1.2
	Standardized designs of parts & subsystems; library of design concepts, design templates	0.7	0.9	0.5/2.1	0.6/2.0
	Product mass	0.5	0.6	0.4/1.1	0.2/1.0
	Government regulations	0.8	1.0	0.8/1.5	1.0/1.5
	Packaging constraints	0.7	0.6	0.3/1.3	0.5/1.5
	Ease of manufacture and assembly	1.2	1.5	1.1/1.5	0.9/1.7
	Recyclability	0.4	0.7	0.4/0.7	0.2/0.9
	Ease of service/cost of repair	0.4	0.2	0.1/0.7	0.2/0.8
	Product specific performance characteristics	1.5	1.4	1.1/1.8	1.4/1.5
Communication Methods	Electronic communication (i.e., internet / email / ftp)	4.2	4.5	3.4/4.5	3.6/6.0
	Physical face-to-face meetings	3.0	2.0	1.9/4.8	1.4/3.5
	Co-location within a common work area	1.8	1.7	0.9/2.3	1.6/2.8

VIII.4. Scenario 4: Influence of Design Criteria on Body and Communication Methods within the Organization

Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
Communication Methods	Print-based communication (memos, letters, reports, Overnight mail etc.)	1.5	0.7	0.9/2.0	0.2/1.3
	Interactive computer tools and use of common databases	1.2	1.4	0.4/2.1	0.7/2.9
	Voice mail and fax	1.1	1.2	0.9/2.3	0.9/2.4
	Video conferencing	0.7	1.0	0.3/1.1	0.8/1.4
	Web-based collaboration tools	0.3	1.5	0.0/1.1	0.4/1.9
	Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.7	0.0/0.8
Human resource management	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
	Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
	Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
	Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
	Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
	Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
	Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
	Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1

VIII.5. ***Scenario 5: Influence of Design Criteria on Body and Communication Methods within the Supply Chain***

Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
Business Philosophy	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
	Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
	Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
	Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
	Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
	Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
	Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1
Organizational Factors	Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
	Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
	Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
	Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
	Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
	Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
	Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
	Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
	Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2
Supplier	Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
	Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
	High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
	Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
	CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3
	Systems integration capabilities (system interaction expertise, full service support, "black box" capability)	0.0	0.1	0.0/0.9	0.0/0.8

VIII.5. ***Scenario 5: Influence of Design Criteria on Body and Communication Methods within the Supply Chain***

Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
Supplier	Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Design Methods	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
	Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
	Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
	Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
	Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
	Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
	Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
	Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7
Design Tools	Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
	Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
	Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
	Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
	Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
	Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
	Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
	Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
	Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
	Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
	Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
	Clay models	0.0	0.0	0.1/0.9	0.3/1.1
	Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
	Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0
Design Criteria	Final product cost	2.1	2.0	0.8/2.8	1.0/2.7
	Aesthetics / styling	1.4	1.5	1.3/1.5	0.7/1.9
	Available product development time / budget	1.3	1.7	0.0/1.4	0.0/1.7
	Product safety / liability	1.1	1.2	1.0/1.3	1.2/1.4
	Product quality, reliability, and durability	0.9	0.9	0.8/1.0	0.9/1.2
	Standardized designs of parts & subsystems; library of design concepts, design templates	0.7	0.9	0.5/2.1	0.6/2.0
	Product mass	0.5	0.6	0.4/1.1	0.2/1.0
	Government regulations	0.8	1.0	0.8/1.5	1.0/1.5
	Packaging constraints	0.7	0.6	0.3/1.3	0.5/1.5
	Ease of manufacture and assembly	1.2	1.5	1.1/1.5	0.9/1.7
	Recyclability	0.4	0.7	0.4/0.7	0.2/0.9
	Ease of service/cost of repair	0.4	0.2	0.1/0.7	0.2/0.8
	Product specific performance characteristics	1.5	1.4	1.1/1.8	1.4/1.5
Communication Methods	Electronic communication (i.e., internet / email / ftp)	4.2	3.8	2.8/6.3	3.1/7.2
	Physical face-to-face meetings	2.3	2.1	2.1/3.6	1.5/2.8
	Co-location within a common work area	0.0	0.9	0.0/0.6	0.0/1.6

VIII.5. ***Scenario 5: Influence of Design Criteria on Body and Communication Methods within the Supply Chain***

Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
Communication Methods	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.1	1.5	0.7/3.4	0.5/2.0
	Interactive computer tools and use of common databases	1.3	1.1	0.5/1.5	0.2/2.8
	Voice mail and fax	2.5	2.0	1.3/2.9	1.3/3.1
	Video conferencing	0.5	0.9	0.0/0.7	0.2/1.5
	Web-based collaboration tools	0.8	1.5	0.0/1.4	0.8/1.8
	Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.6	0.0/1.4
Human resource management	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
	Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
	Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
	Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
	Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
	Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
	Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
	Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1

VIII.6. Scenario 6: Influence of Design Criteria on Body and Communication Methods with the Customer

Area	Category	Median		Quartile (25/75)	
		2004	**2009**	**2004**	**2009**
Business Philosophy	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
	Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
	Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
	Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
	Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
	Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
	Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1
Organizational Factors	Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
	Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
	Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
	Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
	Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
	Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
	Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
	Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
	Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2
Supplier	Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
	Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
	High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
	Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
	CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3
	Systems integration capabilities (system interaction expertise, full service support, “black box” capability)	0.0	0.1	0.0/0.9	0.0/0.8

VIII.6. Scenario 6: Influence of Design Criteria on Body and Communication Methods with the Customer

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Supplier	Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Design Methods	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
	Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
	Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
	Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
	Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
	Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
	Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
	Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7
Design Tools	Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
	Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
	Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
	Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
	Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
	Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
	Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
	Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
	Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
	Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
	Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
	Clay models	0.0	0.0	0.1/0.9	0.3/1.1
	Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
	Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0
Design Criteria	Final product cost	2.1	2.0	0.8/2.8	1.0/2.7
	Aesthetics / styling	1.4	1.5	1.3/1.5	0.7/1.9
	Available product development time / budget	1.3	1.7	0.0/1.4	0.0/1.7
	Product safety / liability	1.1	1.2	1.0/1.3	1.2/1.4
	Product quality, reliability, and durability	0.9	0.9	0.8/1.0	0.9/1.2
	Standardized designs of parts & subsystems; library of design concepts, design templates	0.7	0.9	0.5/2.1	0.6/2.0
	Product mass	0.5	0.6	0.4/1.1	0.2/1.0
	Government regulations	0.8	1.0	0.8/1.5	1.0/1.5
	Packaging constraints	0.7	0.6	0.3/1.3	0.5/1.5
	Ease of manufacture and assembly	1.2	1.5	1.1/1.5	0.9/1.7
	Recyclability	0.4	0.7	0.4/0.7	0.2/0.9
	Ease of service/cost of repair	0.4	0.2	0.1/0.7	0.2/0.8
	Product specific performance characteristics	1.5	1.4	1.1/1.8	1.4/1.5
Communication Methods	Electronic communication (i.e., internet / email / ftp)	4.2	4.4	3.8/6.0	3.2/8.0
	Physical face-to-face meetings	2.8	2.0	2.1/3.2	1.4/3.2
	Co-location within a common work area	0.5	1.5	0.2/1.2	0.0/1.6

VIII.6. Scenario 6: Influence of Design Criteria on Body and Communication Methods with the Customer

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Communication Methods	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.6	0.8	0.8/3.6	0.3/1.8
	Interactive computer tools and use of common databases	1.2	1.4	0.3/1.5	0.4/3.0
	Voice mail and fax	1.5	1.6	1.3/3.5	0.8/2.6
	Video conferencing	0.5	0.8	0.0/0.8	0.4/1.0
	Web-based collaboration tools	0.8	1.6	0.0/1.3	0.8/2.3
	Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.5	0.0/1.1
Human resource management	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
	Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
	Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
	Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
	Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
	Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
	Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
	Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1

VIII.7. Scenario 7: Influence of Design Criteria on Engines/Transmissions and Communication Methods within the Organization					
Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
Business Philosophy	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
	Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
	Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
	Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
	Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
	Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
	Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1
Organizational Factors	Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
	Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
	Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
	Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
	Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
	Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
	Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
	Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
	Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2
Supplier	Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
	Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
	High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
	Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
	CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3

VIII.7. Scenario 7: Influence of Design Criteria on Engines/Transmissions and Communication Methods within the Organization

Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
	Systems integration capabilities (system interaction expertise, full service support, “black box” capability)	0.0	0.1	0.0/0.9	0.0/0.8
Supplier	Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Design Methods	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
	Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
	Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
	Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
	Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
	Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
	Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
	Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7
Design Tools	Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
	Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
	Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
	Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
	Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
	Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
	Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
	Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
	Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
	Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
	Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
	Clay models	0.0	0.0	0.1/0.9	0.3/1.1
	Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
	Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0
Design Criteria	Final product cost	3.4	2.5	2.3/3.9	1.8/3.6
	Aesthetics / styling	1.6	1.7	1.3/2.7	0.9/2.3
	Available product development time / budget	0.0	0.0	0.0/0.0	0.0/0.0
	Product safety / liability	1.1	0.0	0.0/2.4	0.0/0.6
	Product quality, reliability, and durability	2.0	1.7	1.7/2.9	1.1/2.2
	Standardized designs of parts & subsystems; library of design concepts, design templates	1.2	1.5	0.8/2.3	0.9/2.3
	Product mass	1.0	1.0	0.8/1.9	0.8/1.8
	Government regulations	0.8	0.4	0.0/2.1	0.0/2.1
	Packaging constraints	1.6	1.5	1.3/3.2	1.4/2.1
	Ease of manufacture and assembly	0.3	0.2	0.0/1.1	0.0/0.7
	Recyclability	0.0	0.0	0.0/1.1	0.0/0.8
	Ease of service/cost of repair	0.0	0.0	0.0/0.0	0.0/0.3
	Product specific performance characteristics	3.2	2.6	2.2/4.0	1.9/3.7

VIII.7. Scenario 7: Influence of Design Criteria on Engines/Transmissions and Communication Methods within the Organization

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Communication Methods	Electronic communication (i.e., internet / email / ftp)	4.2	4.5	3.4/4.5	3.6/6.0
	Physical face-to-face meetings	3.0	2.0	1.9/4.8	1.4/3.5
	Co-location within a common work area	1.8	1.7	0.9/2.3	1.6/2.8
Communication Methods	Print-based communication (memos, letters, reports, Overnight mail etc.)	1.5	0.7	0.9/2.0	0.2/1.3
	Interactive computer tools and use of common databases	1.2	1.4	0.4/2.1	0.7/2.9
	Voice mail and fax	1.1	1.2	0.9/2.3	0.9/2.4
	Video conferencing	0.7	1.0	0.3/1.1	0.8/1.4
	Web-based collaboration tools	0.3	1.5	0.0/1.1	0.4/1.9
	Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.7	0.0/0.8
Human resource management	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
	Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
	Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
	Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
	Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
	Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
	Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
	Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1

VIII.8. Scenario 8: Influence of Design Criteria on Engines/Transmissions and Communication Methods within the Supply Chain

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Business Philosophy	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
	Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
	Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
	Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
	Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
	Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
	Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1
Organizational Factors	Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
	Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
	Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
	Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
	Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
	Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
	Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
	Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
	Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2
Supplier	Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
	Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
	High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
	Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
	CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3

VIII.8. Scenario 8: Influence of Design Criteria on Engines/Transmissions and Communication Methods within the Supply Chain

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
	Systems integration capabilities (system interaction expertise, full service support, "black box" capability)	0.0	0.1	0.0/0.9	0.0/0.8
Supplier	Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Design Methods	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
	Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
	Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
	Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
	Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
	Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
	Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
	Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7
Design Tools	Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
	Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
	Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
	Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
	Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
	Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
	Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
	Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
	Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
	Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
	Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
	Clay models	0.0	0.0	0.1/0.9	0.3/1.1
	Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
	Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0
Design Criteria	Final product cost	3.4	2.5	2.3/3.9	1.8/3.6
	Aesthetics / styling	1.6	1.7	1.3/2.7	0.9/2.3
	Available product development time / budget	0.0	0.0	0.0/0.0	0.0/0.0
	Product safety / liability	1.1	0.0	0.0/2.4	0.0/0.6
	Product quality, reliability, and durability	2.0	1.7	1.7/2.9	1.1/2.2
	Standardized designs of parts & subsystems; library of design concepts, design templates	1.2	1.5	0.8/2.3	0.9/2.3
	Product mass	1.0	1.0	0.8/1.9	0.8/1.8
	Government regulations	0.8	0.4	0.0/2.1	0.0/2.1
	Packaging constraints	1.6	1.5	1.3/3.2	1.4/2.1
	Ease of manufacture and assembly	0.3	0.2	0.0/1.1	0.0/0.7
	Recyclability	0.0	0.0	0.0/1.1	0.0/0.8
	Ease of service/cost of repair	0.0	0.0	0.0/0.0	0.0/0.3
	Product specific performance characteristics	3.2	2.6	2.2/4.0	1.9/3.7

VIII.8. Scenario 8: Influence of Design Criteria on Engines/Transmissions and Communication Methods within the Supply Chain

Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
Communication Methods	Electronic communication (i.e., internet / email / ftp)	4.2	3.8	2.8/6.3	3.1/7.2
	Physical face-to-face meetings	2.3	2.1	2.1/3.6	1.5/2.8
	Co-location within a common work area	0.0	0.9	0.0/0.6	0.0/1.6
Communication Methods	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.1	1.5	0.7/3.4	0.5/2.0
	Interactive computer tools and use of common databases	1.3	1.1	0.5/1.5	0.2/2.8
	Voice mail and fax	2.5	2.0	1.3/2.9	1.3/3.1
	Video conferencing	0.5	0.9	0.0/0.7	0.2/1.5
	Web-based collaboration tools	0.8	1.5	0.0/1.4	0.8/1.8
	Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.6	0.0/1.4
Human resource management	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
	Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
	Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
	Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
	Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
	Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
	Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
	Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1

VIII.9. Scenario 9: Influence of Design Criteria on Engines/Transmissions and Communication Methods with the Customer

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Business Philosophy	Increasing design process discipline (i.e., following a specified product development process)	2.5	2.0	1.0/3.5	1.6/2.4
	Increasing math-based engineering (CAE and simulation)	1.8	1.8	1.4/2.6	1.1/2.2
	Increasing global product design (design is done globally)	1.4	1.8	0.2/1.7	0.7/2.6
	Increasing number of carry-over parts or subsystems	1.4	1.8	0.5/1.8	0.3/2.5
	Increasing in-house modular designs / portfolios	1.4	1.4	0.2/2.1	0.0/2.2
	Increasing product design for global manufacturing (manufacturing is done globally)	1.2	1.5	0.1/1.8	0.4/2.3
	Increasing outsourced modular designs / portfolios	0.4	0.8	0.0/1.6	0.2/1.4
	Increasing variations of final product design	0.4	0.5	0.0/1.2	0.0/1.1
Organizational Factors	Increasing discipline in design and development process (e.g., increasing the number of design reviews or employing a design process measurement system)	1.8	1.6	1.5/1.8	1.0/2.1
	Increasing collaboration between you, your customer, and your supply chain	1.1	1.8	0.8/1.4	0.8/2.3
	Increasing integration of computer/software at all levels within your organization	0.9	1.0	0.7/1.6	0.2/1.7
	Increasing collaboration at all levels within your organization	0.9	0.9	0.5/1.7	0.4/1.3
	Increasing supplier contribution to developmental work	0.6	0.8	0.4/1.4	0.5/1.6
	Outsourcing of engineering (core design or remedial tasks)	0.5	0.8	0.2/0.5	0.5/1.2
	Utilizing / creating specialized skill sets throughout the world, within your organization, or with partner organizations	0.5	1.2	0.2/1.4	0.2/2.5
	Increasing integration of computers / software between you, your customer, and your supply chain	0.3	0.8	0.0/0.9	0.2/1.4
	Combining design and engineering functions (e.g., requiring designers to have a 4 yr. engineering degree)	0.3	0.5	0.0/0.7	0.1/1.2
Supplier	Providing lowest cost product / service	1.8	1.6	0.8/3.8	0.7/2.5
	Full design and testing capability	0.9	0.8	0.3/1.0	0.5/1.2
	High level of experience in the automotive field	0.8	1.0	0.6/1.4	0.4/1.3
	Technological innovation (product, mfg., etc.)	0.6	1.2	0.4/1.2	0.9/1.4
	CAE / CAD / CAM capabilities (employee skill level & technology sophistication)	0.6	0.9	0.4/1.4	0.2/1/3

VIII.9. Scenario 9: Influence of Design Criteria on Engines/Transmissions and Communication Methods with the Customer

Area	**Category**	**Median**		**Quartile (25/75)**	
		2004	**2009**	**2004**	**2009**
	Systems integration capabilities (system interaction expertise, full service support, "black box" capability)	0.0	0.1	0.0/0.9	0.0/0.8
Supplier	Proximity of supplier engineering to our engineering headquarters (within ½ day travel)	0.0	0.0	0.0/0.5	0.0/0.3
Design Methods	Design for Manufacture and Assembly	2.5	2.4	1.8/3.3	2.0/3.0
	Design for Reliability and Durability	2.3	2.2	1.0/2.7	1.5/2.6
	Design for Recyclability	0.5	0.6	0.0/0.5	0.5/0.8
	Value Analysis	0.5	0.6	0.3/0.9	0.5/0.7
	Design for Service, Repair and Maintenance	0.5	0.5	0.2/0.9	0.1/1.2
	Design for Ergonomics	0.4	0.5	0.0/1.0	0.0/1.2
	Design for Six Sigma	0.3	1.0	0.1/1.1	0.5/2.1
	Design for Green Manufacturing	0.3	0.6	0.0/0.6	0.1/1.2
	Design for Global Market	0.3	0.6	0.0/0.5	0.4/1.0
	Design for Global Manufacturing	0.1	0.3	0.0/0.3	0.0/0.7
Design Tools	Computer based tools for conceptual design	1.4	1.6	0.0/0.5	0.0/0.3
	Rapid prototyping / physical prototyping	1.4	0.9	0.5/1.1	0.6/1.4
	Product simulation technologies (crash, heat flow, dynamics etc.)	0.9	1.6	0.0/0.6	0.0/0.5
	Designed experiments (DOE)	0.8	1.1	0.8/2.0	0.6/1.1
	Simulation of manufacturing and assembly activities	0.6	0.8	0.0/0.5	0.3/0.9
	Competitive benchmarking	0.5	1.0	0.3/1.1	0.8/1.6
	Parametric design tools	0.5	0.8	0.2/0.9	0.2/0.8
	Quality Function Deployment	0.5	0.7	0.8/1.9	1.0/2.1
	Customized in-house software tools	0.5	0.5	0.2/0.9	0.2/1.2
	Computer aided tolerancing / variation analysis	0.4	0.5	0.5/1.7	0.9/2.0
	Manual drawings / sketches	0.0	0.0	0.1/0.8	0.4/1.1
	Clay models	0.0	0.0	0.1/0.9	0.3/1.1
	Virtual reality	0.0	0.0	0.0/0.2	0.0/0.8
	Artificial intelligence / expert system / neural network	0.0	0.0	0.0/0.2	0.0./0.0
Design Criteria	Final product cost	3.4	2.5	2.3/3.9	1.8/3.6
	Aesthetics / styling	1.6	1.7	1.3/2.7	0.9/2.3
	Available product development time / budget	0.0	0.0	0.0/0.0	0.0/0.0
	Product safety / liability	1.1	0.0	0.0/2.4	0.0/0.6
	Product quality, reliability, and durability	2.0	1.7	1.7/2.9	1.1/2.2
	Standardized designs of parts & subsystems; library of design concepts, design templates	1.2	1.5	0.8/2.3	0.9/2.3
	Product mass	1.0	1.0	0.8/1.9	0.8/1.8
	Government regulations	0.8	0.4	0.0/2.1	0.0/2.1
	Packaging constraints	1.6	1.5	1.3/3.2	1.4/2.1
	Ease of manufacture and assembly	0.3	0.2	0.0/1.1	0.0/0.7
	Recyclability	0.0	0.0	0.0/1.1	0.0/0.8
	Ease of service/cost of repair	0.0	0.0	0.0/0.0	0.0/0.3
	Product specific performance characteristics	3.2	2.6	2.2/4.0	1.9/3.7

VIII.9. Scenario 9: Influence of Design Criteria on Engines/Transmissions and Communication Methods with the Customer

Area	Category	Median		Quartile (25/75)	
		2004	2009	2004	2009
Communication Methods	Electronic communication (i.e., internet / email / ftp)	4.2	4.4	3.8/6.0	3.2/8.0
	Physical face-to-face meetings	2.8	2.0	2.1/3.2	1.4/3.2
	Co-location within a common work area	0.5	1.5	0.2/1.2	0.0/1.6
Communication Methods	Print-based communication (memos, letters, reports, Overnight mail etc.)	2.6	0.8	0.8/3.6	0.3/1.8
	Interactive computer tools and use of common databases	1.2	1.4	0.3/1.5	0.4/3.0
	Voice mail and fax	1.5	1.6	1.3/3.5	0.8/2.6
	Video conferencing	0.5	0.8	0.0/0.8	0.4/1.0
	Web-based collaboration tools	0.8	1.6	0.0/1.3	0.8/2.3
	Virtual environment (i.e., video conferencing in combination with virtual reality)	0.0	0.0	0.0/0.5	0.0/1.1
Human resource management	All interested parties (e.g., purchasing, engineering, manufacturing, marketing, etc.) working towards common goals in an effective manner	1.8	2.6	0.8/2.6	1.0/3.0
	Product design accommodating process design and process capabilities	1.5	1.5	0.9/2.2	1.1/2.8
	Practices and procedures to maintain core competencies	1.5	1.2	0.5/2.6	0.9/2.4
	Stability of workforce	1.4	1.0	0.9/1.9	0.6/1.6
	Higher levels of education / expertise of personnel in product, manufacturing processes, design tools and methods, etc.	1.0	1.2	0.9/1.8	0.7/1.9
	Effective distribution of best practices throughout the cross-function product-development staff	0.9	1.4	0.5/1.5	1.0/2.1
	Sharing of ideas between groups / platforms / departments	0.7	0.9	0.5/1.0	0.8/1.7
	Management being open to new ideas and entrusting the design and manufacturing issues to technical personnel	0.6	1.0	0.5/1.6	0.8/1.1